JULY 1960

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ILLUMINATING ENGINEERING

Journal of the
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TECHNICAL SESSIONS

Monday afternoon

Light Sources I — Applications I

Tuesday morning

Research — Light Sources II

Tuesday afternoon

Applications, Light Sources I — Residence Lighting Forum

Applications, Light Sources II

Tuesday evening

"Progress in Lighting"

Wednesday morning

Applied Lighting Competition

Thursday morning

Roadway Lighting — Fluorescent Ballasts

Thursday afternoon

Photometry — Applications II

SOCIAL EVENTS

Sunday afternoon

Informal Reception

Wednesday afternoon

River Cruise and Chicken Barbecue

or

Golf at Edgewood Country Club

Thursday evening

President's Reception, Banquet and Dance (dress optional)

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Every event mentioned above *plus*

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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BEFORE "Operation UPlight" Assembly Products, Inc., of Chesterland, Ohio, had to supplement their general lighting system with additional fixtures to provide sufficient illumination at work levels for their precision manufacturing operations. This combination resulted in extreme brightness variations.

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"The combination of at least 300 footcandles along with the determination of the most practical mounting height (7' 6") made the selection of the lighting fixture at Assembly Products, Inc. an extremely critical consideration,"

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"However, after seeing the results of the installation, we were firmly convinced that our choice of Day-Brite CFI-30 Power-Groove Industrials was right. The resulting low-brightness and high efficiency are evident to all; most importantly to the people working in the area because it eliminates eye fatigue.

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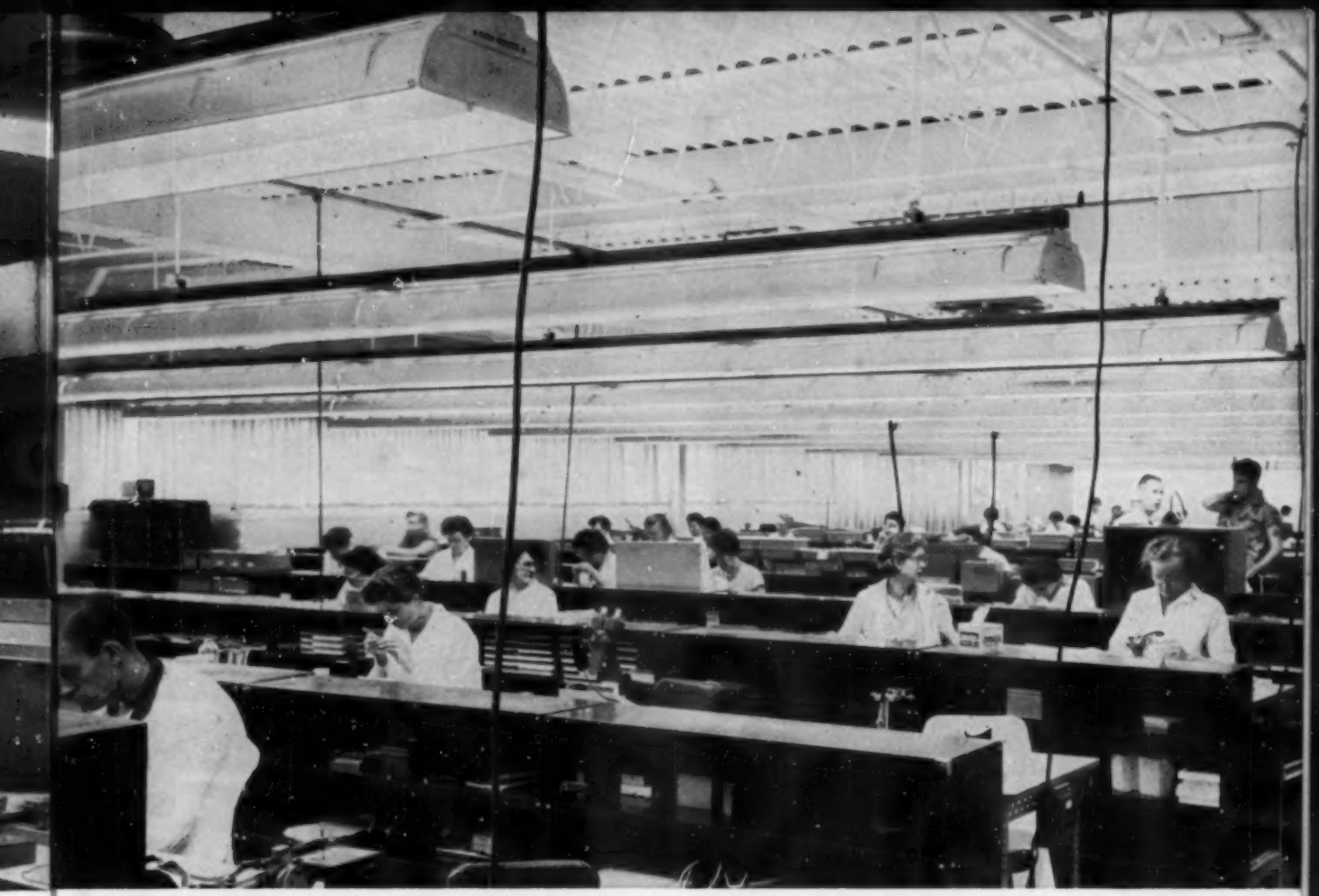
"The excellence of the results, plus the fine handling of the order by Day-Brite factory and local representatives, have given us another outstanding job, fully appreciated by Mr. Saint Amour (President, Assembly Products) and myself. This is an example of another Day-Brite installation well received and appreciated."

A. J. Eichmuller (right) and Day-Brite representative Tony Dunn examine the Day-Brite CFI-30.



AFTER "Operation UPlight" Day-Brite CFI-30 fixtures, equipped with Power-Groove lamps, boosted illumination to 300 footcandles and balanced brightness with 22½% uplighting. Fixtures were mounted in continuous rows on 7-foot centers, 7½ feet above the floor. The ACTUAL difference is even greater than these photographs show.

for 300 footcandles

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For actual cost figures comparing Day-Brite CFI fixtures with other lighting systems, call your Day-Brite representative listed in the Yellow Pages. See for yourself why hundreds of companies across the country have put "Operation UPlight" into action, making it the most successful program in Day-Brite history. PHONE TODAY!

**per footcandle for each 10,000 square feet. Based on 4,000-hour operation, 1¢ per KWH rate, 35% lamp discount, typical maintenance cost, and amortizing the cost of buying and installing the lighting units over a ten year period.*

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Here's another example of LITECONTROL easy-on-the-eyes lighting that increases office efficiency. You'll find this type of eminently practical lighting throughout the new offices of Gulf Oil Corporation, Philadelphia Division. Also in one of Gulf's Pittsburgh buildings where the same kind of fixtures were recently installed.

A 3′ x 4′ troffer is used in the inverted "T" Grid ceiling. This fixture replaces a 3′ x 4′ ceiling panel. Thus, if desired, the fixtures could be moved, without disturbing the ceiling structure.

The troffer features a formed vinyl plastic diffuser which fits snugly in the fixture. No metal shows and there are no light leaks. Result: 3′ x 4′ modules or units which shed evenly diffused, low brightness illumination. The same diffusers, which have structural ribs for rigidity, are also used in an overall luminous ceiling in Gulf's Engineering Department Drafting Room.

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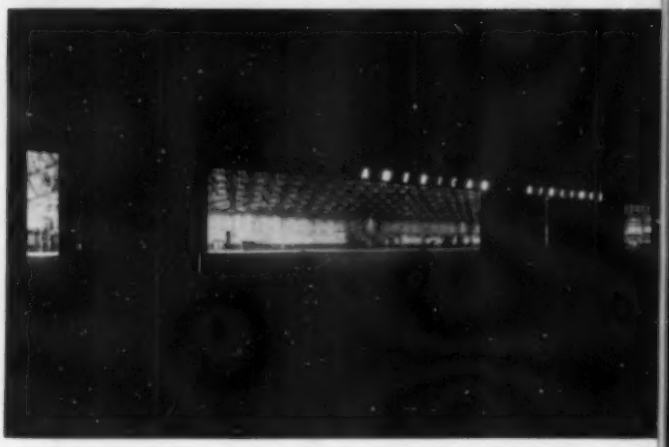


American Airlines Specifies . . .

New Lighting for Idlewild Hangar

By DANIEL J. O'NEILL

AMERICAN AIRLINES' recently completed hangar (photos at top) at New York's Idlewild Airport has more than three times the illumination of most airplane hangars. The huge building, large enough to shelter ten giant new jets simultaneously, is integrated with American's new Idlewild passenger terminal.

The hangar lighting level is such that no portable stanchion lights are required, even for close-up mechanical work, and there are no discernible shadows beneath berthed planes. Color-corrected, mercury-vapor lamps, housed in high-bay prismatic glass reflectors, were selected for the lighting job, which is outlined below.

The over-all hangar is 756 feet long by 356 feet wide. It is partitioned into three longitudinal sections by two walls. Two outer hangar sections, each 140 feet wide, are for planes and the 74-foot-wide center section is for offices, classrooms and storage areas. The two partition walls are recessed at five equally spaced intervals to accommodate the jets' noses (see photo on following page).

The roof is supported on cantilever trusses mounted on columns built into the partition walls. The lower members of the trusses rise from a height of approximately 32 feet at the partition wall to approximately 44 feet at the outside wall. This high outside wall gives clearance for the tails of the jet liners. Other relatively new Idlewild hangars have had to be altered to accommodate the high statilizers of the new jets.

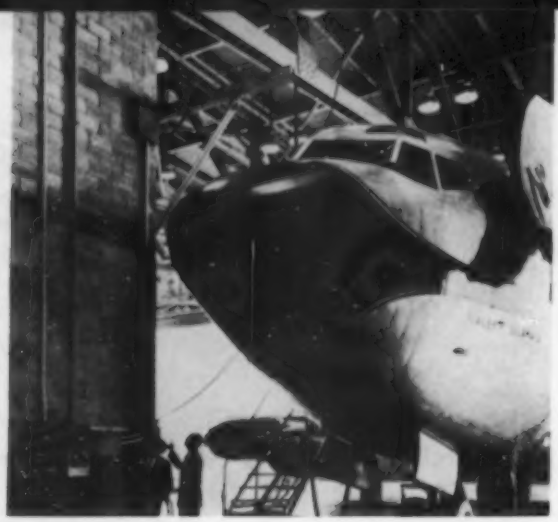
In planning the lighting system, desired illumination level, most suitable lighting equipment, structural restrictions and maintenance requirements were taken into consideration.

Desired illumination level was determined by airline engineers after conferring with their engineering consultants, and it was decided that a maintained uniform level of 60 to 65 footcandles would be specified two feet, six inches above the hangar floor. Footcandle readings in most existing hangars range well down into the 20's and below.

Consulting engineers then estimated the total lumens required to illuminate the hangar areas. This, in turn, enabled calculation of the number of lamps required, and these calculations were made for both fluorescent and mercury-vapor systems. Each five-ship, 140-foot by 756-foot area required: (a) 858 eight-foot, two-lamp, 1500 milliampere fluorescent luminaires with a connected load of 412 kw, or (b) 740 open-bottom, open-top, prismatic glass high-bay reflectors with 400-watt, color-corrected, mercury-vapor lamps having a connected load of 333 kw. Based largely on these factors, the mercury-vapor system was selected.

From a maintenance standpoint, it was decided to use fixed lights with a mobile elevating platform for lamp replacement. Under present operating schedules, burned-out lamps are replaced monthly; to date, an average of 15 per month in 1440 mer-

AUTHOR: Manager, Industrial Lighting, Holophane Co., Inc., New York, N. Y.



cury-vapor outlets have been replaced—an amount easily handled by the maintenance crew.

In specifying mercury-vapor lamps, there was a choice between single 1000-watt units and twin 400-watt units. Economics slightly favored single units but practical considerations pointed to the twin units. Structural members of the trusses made spacing of the 1000-watt units difficult—if spaced as required to provide the desired illumination, spacing would not be symmetrical and would conflict with structural elements in some locations. If spaced uniformly, more units than necessary would have been required. Therefore, twin 400-watt units were installed (see drawing). The twin units have the added advantage of reducing interception of light by planes in the hangar; the more lighting units there are, the less the obstruction of light output by objects in lighted areas.

Luminaires were spaced on 20-foot centers across the hangar, but due to the location of 20-foot-on-center roof trusses and interconnecting members, they were placed on 15-foot centers in the lengthwise direction. They are at the same heights as lower surfaces of the roof trusses. In most locations, twin units straddle crossed struts which brace lower members of adjacent trusses. Nose-bay light spacing is the same as in the hangar proper.

With spacing selected, illumination was checked according to the "point-by-point" method. Using this method, total footcandles at selected points in a typical 200-square-foot area were calculated. This was done by determining which lamps would illuminate each point, calculating illumination supplied by each luminaire and totaling these values. These calculations, later verified with a cosine and color-corrected illumination meter, indicated that the selected spacing was entirely satisfactory for meeting original design criteria.

Power for the installation is taken from a 480/277-volt bus running above the rooms of the center section. More than fifty 277-volt lighting circuits are connected with the main bus and each circuit includes four to six twin, prismatic high-bay reflectors and two-lamp regulated mercury-vapor transformers. Five control panels are spaced along each partition wall so that lighting for given hangar areas can be controlled from within the area.

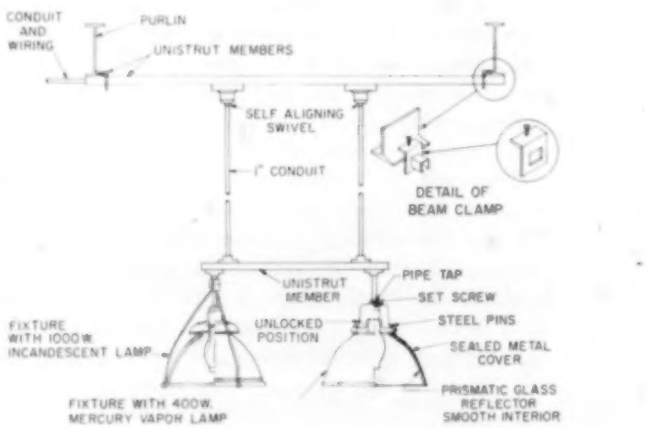
Mercury lamps in a given location are operated only when an airplane is in the immediate zone. Otherwise, 1000-watt incandescent "night lights" provide enough light for "walk through" purposes.

Incandescent lamps, on 60-foot centers in one direction and 76-foot centers in the other, replace one member of the twin units at periodic intervals. They illuminate immediately and do not require the brief warm-up period of the mercury-vapor units. Incandescents are on independent circuits serviced from 277/115-volt dry type transformers.

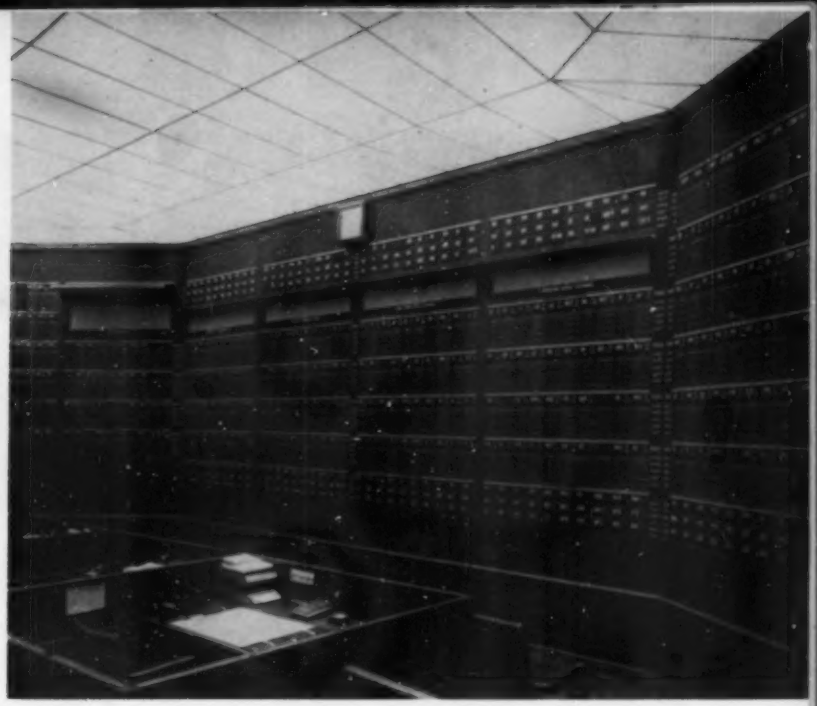
The luminaires are of the high-bay type with light output distributions especially suited for mounting heights of 32 to 44 feet, as required on this job. The smooth interiors of the prismatic glass reflectors do not collect air-borne dust nor are they affected by corrosion from seashore atmosphere, in which the hangar is located. The deep contours of the prismatic reflectors provide 35-degree shielding of the 400-watt mercury lamps, making bottom louvers or similar devices unnecessary.

Supervisory and maintenance personnel in this new American Airlines hangar are completely satisfied with the operation and performance of their high-bay, color-corrected, mercury-vapor lighting system. In addition, other airline operators have inspected this installation with the intention of improving existing facilities and adopting similar systems for hangars presently in design stages.

Architects for the hangar were Kahn & Jacobs; Clifton E. Smith and Jaros, Baum & Bolles were consulting engineers; Turner Construction Co. was general contractor and Lord Electric was electrical subcontractor; all are of New York City.



Stocks Are Looking Brighter



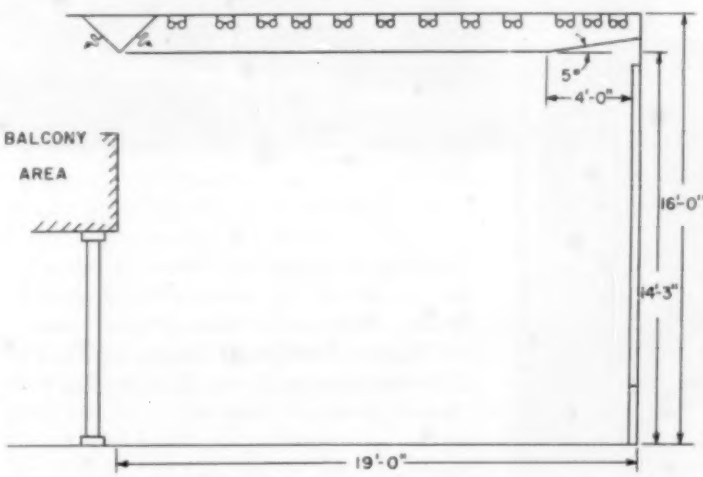
AMONG THE things which are "going up" on the stock board at Courts and Co., Atlanta brokerage house, is the level of illumination—from the newly installed luminous ceiling system. The three-lamp troffers of the old lighting system have been replaced by three rows of two-lamp 1500-ma fixtures mounted above a ⅜-inch baked white honeycomb ceiling. The ceiling follows the contour of the stock board, with all linear sources plotted and engineered to the board.

A section through the room (see drawing below) shows that the greatest viewing angle is from a position underneath the balcony, viewing the top row of number on the board. For more light on the board and less brightness from this viewing angle, the four-foot ceiling sections closest to the board were lifted to a five-degree angle. Shielding of the projecting ticker tape permitted the utilization of this lift.

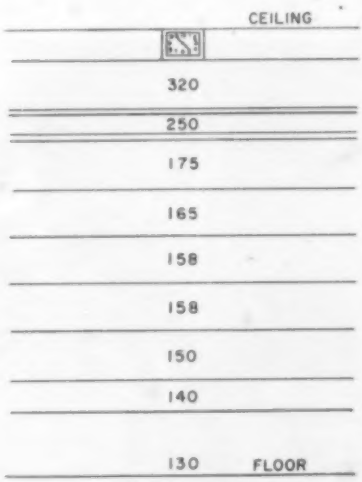
Footcandle readings on the board range from a maximum of 320 footcandles at the top to 150 at the bottom, with the greatest part of the board reading in the 150- to 175-fc range (see chart).

In the general room area, a continuation of the luminous ceiling with two-lamp 800-ma fixtures over ¼-inch baked white honeycomb diffusers results in 150 footcandles, evenly distributed at desk level, with good brightness ratios from any point in the room.

Lighting designed by S. J. Andre, Georgia Power Co., Atlanta. Installation won first place in Georgia Section's Applied Lighting Competition.



Section through stock board room.



Footcandle readings on board.

Small Boat Moorage On Puget Sound

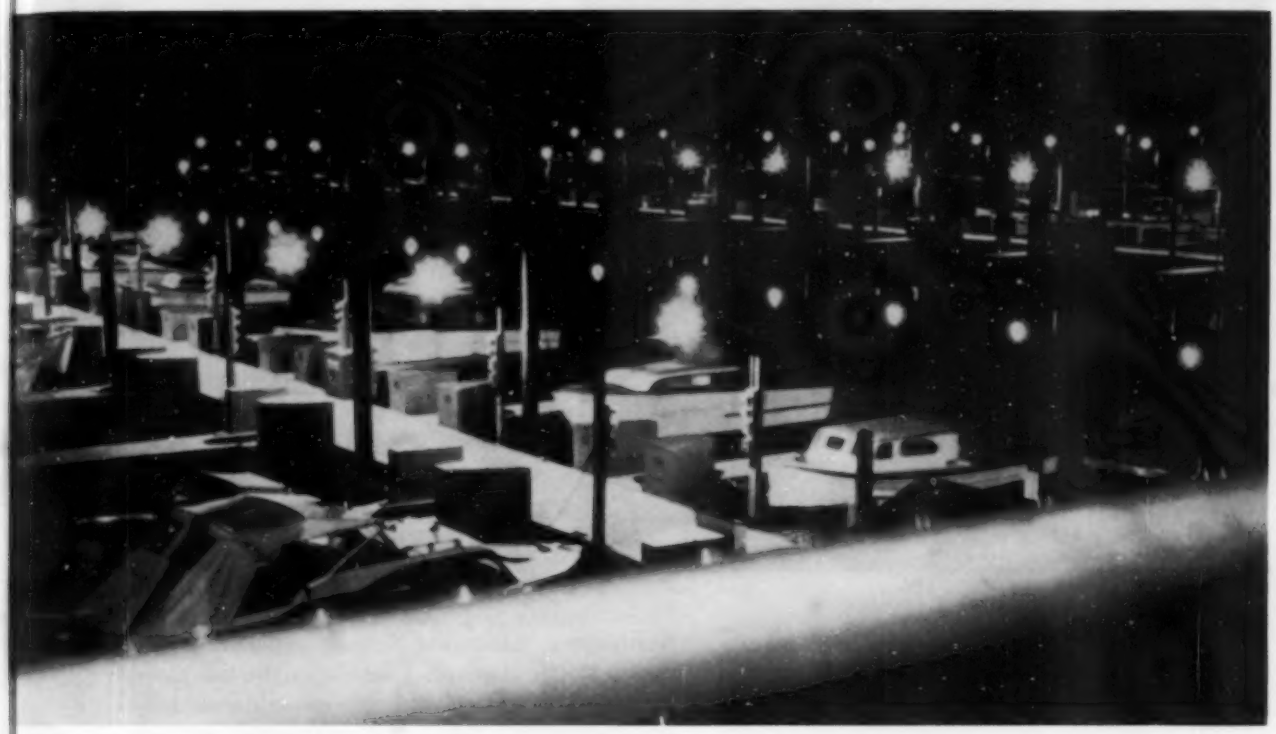
Filling a gap in lighting application literature, this installation for a small boat moorage, the first of its kind reported in IE, offers one solution to a lighting problem, certain to become common, as the popularity of pleasure boating continues to soar.

Shilshole Bay Marina on Puget Sound is being constructed by the City of Seattle over a three-year period (1959-1961) in response to a demand for facilities created by the popularity of the nation's newest mass leisure time activity—boating. The first phase of the project, which was completed in 1959, was the construction of a moorage for pleasure and fishing boats and other small craft, an L-shaped pier and six lightweight concrete floats ranging in length from 500 to 600 feet. Lighting specifications were for a uniform level of illumination to be supplied by a system designed for easy maintenance and resistance to salt spray corrosion by the sea water.

Nighttime view of promenade, looking north (right). Pier and promenade are lighted by 250-watt improved color mercury lamps housed in corrosion-resistant luminaires.

Nighttime view of moorage float "C" (below). A series of arbors, making use of vertical structural members installed for float servicing equipment, provide luminaire mounting locations.

Lighting designed by James H. Skog, B. A. Travis & Associates, Seattle, Wash. Installation won second prize in Pacific Northwest Region Applied Lighting Competition; first in Puget Sound Section's contest.



Pier and Promenade Lighting

Pier lighting design specified the installation of twenty-foot standards, constructed of a special alloyed aluminum (No. 6063-T6), highly resistant to salt corrosion, on 75-foot centers. Post-mounted on top of the standards are corrosion resistant anodized aluminum reflectors hinged to the top of a soda lime refractor and equipped with a 250-watt improved-color mercury lamp (H2KF/C), chosen for its long life and good maintenance efficiency. The lamp is used with a constant wattage ballast operating from a 240-volt system, housed in the aluminum base of the standard.

Refractor used along the promenade and pier produces an IES Type II light distribution with considerable spill light on the ends of the moorage floats to reduce hazards during evening hours. Measured illumination intensities at grade levels were 1.5 footcandles near the luminaires, .3 to .75 footcandle between luminaires.

Float Lighting

Since vertical structural members were installed to support metering and servicing equipment for the float stalls, it was logical to make use of these members in mounting the float lighting system. Lighting and servicing wiring was combined in the same conduit and the two sections of conduit joined at the center of the float walkway with a T-conduit which is used to support the luminaire. This formed a series of arbors over the walkway from one side of the float to the other, allowing a spacing of 30 to 35 feet for luminaires.

Because of the relatively low mounting and short lamp spacing, incandescent lighting was chosen for the floats. Luminaire selected was constructed of an anodized aluminum hood, two-piece prismatic glass refractor and cast aluminum base. It is equipped with a 150-watt A-231F lamp. Like the luminaire used on the pier, this unit is easily maintained and highly resistant to the corrosive action of the sea spray.

The asymmetric light distribution with lateral distribution alternated between lamps produces 2.3 footcandles on the float walkway under the luminaires and .8 footcandle between luminaires.

The entire system of pier, promenade and float lighting is connected to two groups of circuits, with luminaires alternately circuited for two levels of illumination. Lighting is controlled by a time switch and photoelectric switch. At about 10 p.m., when the use of the moorage area is minimal, the time switch cuts off one circuit, leaving half the lighting on for safety. At 4 p.m. the following day, the time switch closes and the photoelectric switch, set to turn on the lighting when daylight illumination drops to two footcandles, is in complete control.

Dual-Purpose Design

With the tremendous boom in construction during the last decade, the design of lighting for areas which are half old, half new has become one of the most interesting and recurrent problems faced by lighting engineers. New buildings offer optimum designing conditions, the opportunity to plan good lighting, integrated with the architecture from the blueprint stage. The problem occurs in the design for the remodeled section, where it is necessary to fit an esthetically compatible system to predetermined structural limitations.

Solution to this old/new problem at the First National Bank of Florence, Alabama was the success of continuous cooperation between architects Northington, Smith and Kranert and lighting designer M. R. Hazzard, Hazzard, McRoy & Cone, Birmingham, Ala. Their experiences demonstrate one approach to the problem which may serve as a useful guide to others facing similar situations.

Initial step in the architectural plan was the closing of the front of the existing building with a facade of unpolished stone, trimmed with a backlighted metal sign. In contrast to this solid wall of stone are the glass panels that dominate the facade of the new building. Slender stone columns accented by recessed baffled downlights with 150-watt PAR 38 spots at the head of the canopy, between columns, frame the expanse of glass.

Dominant interior features of the new building, the mosaic tiled lobbies and open stairwell, are lighted from deep baffled incandescent downlights with R40 floodlamps in a continuation of the outdoor lighting pattern. Emphasis on the stairway is obtained from the specially designed ceiling-mounted chandelier made of five tiers of milk white acrylic cylinders, 6 inches in diameter, 18 inches tall. The chandelier hangs from a 21-foot aluminum shaft suspended over the stairwell.

To the right of the new building entrance is the main banking area where eight-lamp 40-watt, four-by four-foot recessed troffers with low brightness lens and recessing splay trim give a general illumination level of 110 footcandles. A scaled-down repeat of one tier of the stairway chandelier is hung over each of the customer writing desks for decorative continuity.

Where the main banking area ends and the loan department begins is the line between the new and old buildings. To give a feeling of spaciousness in the loan department, where a lower ceiling and structural columns create a contrast to the adjacent main area, two- by eight-foot troffers in continuous rows are used for lighting. The troffers, equipped with diffusing lenses and recessing splay similar to that used in the main banking area, produce an average illumination level of 125 fc.

Lighting system in a work area behind the public spaces of the bank uses continuous rows of three-lamp, 40-watt rapid-start troffers with plastic lens diffusers. This selection, made for architectural design considerations, despite the lower efficiency of three-lamp troffers, permitted the installation of fewer units, on a wider spacing, which resulted in a lighting intensity of 115 footcandles.

For the accounting department offices on one of the upper floors of the bank building (not shown) plastic-sided fixtures with metal louvers are mounted in continuous rows on the high portion of the ceiling with a perpendicular row of luminaires installed beneath a furred-down duct to give light on a windowless wall.

In other areas of the building, private offices and a conference room, the troffer is used in a variety of ways to meet individual requirements. The final impression of the building is of standard equipment and practical design techniques fused for a comfortable working environment.

General merchandising area in Daniel's Pharmacy is lighted by continuous rows of recessed troffers. Note surface-mounted units over drug counter in background.

Lunch counter has recessed fluorescent troffers for general illumination level of 250 footcandles in work area, surface-mounted incandescent downlights for accent.

Advertise with Light

THE CORNER drugstore with the kindly "Doc" dispensing prescriptions and advice is gradually being replaced by the "supermarket" pharmacy, a slick business operation where the drug trade is taking a back seat to the sale of a variety of goods from paperback books to small appliances. Coincidental with this shift in function is a change in the appearance of the pharmacy. The small shop is being outmoded by the sleek modern lines of a store designed to function not only as a merchandising area, but as an advertising and selling tool in itself.

The role of lighting as an aid to the "advertising" function of the architectural design was as important as its role in creating a comfortable seeing environment at Daniel's Pharmacy, Memphis, Tenn. The architectural design of the store works toward an impression of spaciousness—long, low lines and a wide expanse of glass set in the center of a large area. The lighting repeats this design motif and maintains the smooth uninterrupted lines of the building design. Long lines of recessed troffers and surface-mounted units result in an uncluttered ceiling, free of air ducts, conduit and exposed structure.

Throughout the general merchandising area, four-foot, four-lamp troffers with 40-watt cool white rapid-start lamps are mounted in continuous rows on eight-foot centers at a height of 11 feet. Average illumination level, after 300 hours of operation, was 197 footcandles. Over the snack bar, the recessed troffers mounted at 8½ feet above the floor supply general illumination; surface-mounted incandescent downlights accent the counter top. Illumination level in the work area behind the counter measured 250 footcandles, with 265 on the counter surface.

For the pharmacy at the rear of the store, surface-mounted, four-foot, two-lamp, rapid-start units with plastic diffusers and plastic side panels are run in continuous rows over the drug counter. Fixtures are placed in line with the back edge of the counter for maximum illumination on the work surface and minimum glare from the low (8½-foot) mounting. Illumination intensity on the drug counter was 132 footcandles after 300 hours.

These same surface-mounted units, used in the stock room, produce vertical footcandle levels of 85 at the top shelf and 40 one foot from the floor, well above the IES recommended minimums.

Secondary components of the lighting design are surface reflectances—ceiling, 85 per cent RF; walls, 65 per cent RF; floors, 50 per cent RF.

Installation designed by Charles D. Hooper, Memphis Light, Gas & Water Division, Memphis, Tenn., tied for third prize in South Central Region's Applied Lighting Competition, after having won first place in Mid-South Chapter's contest.

Adaptation on Runway and Turnpike

By DOMINA EBERLE SPENCER
S. C. PEEK

The relative visibility (delos) method was proposed by Moon and Spencer in 1945 as a method of including the effect of quantity and quality of light on vision. In the paper, this method is extended to vision in fog. Practical applications are made to a comparison of visual conditions under several systems of illumination on runway and turnpike, in clear weather and in fog.

THE ENGINEERING of outdoor lighting has generally neglected the state of adaptation of the eye. Since quantities of light available on runway and turnpike are low, it is true that marked improvement in vision can frequently be attained by merely using more powerful lamps. However, it is by no means always possible to obtain improved vision by considering only the incident light on the pavement. Actually, the "footcandles" on the pavement give no information of direct visual significance. As the pavement is far from a perfectly diffusing surface,[1] the specification of the incident light tells nothing about the appearance of the pavement to pilot or driver. And since outdoor fields of view are highly non-uniform, improvement in vision may have little to do with quantity of light. Greater and more economical improvement in vision can often be obtained by controlling[2] the light from a small number of lamps than from employing many powerful lamps with little or no control of the distribution of light.

The effect of the non-uniformity in the field of view is studied most effectively by specifying the state of adaptation[3] of the eye. In the discussion[4] of a commendable paper on street lighting by Rex,[5] one of the authors suggested that a simple and effective method (based on a wide array of visual data) should be applied to solving outdoor lighting problems.

The present paper carries out the suggestion set forth at the Toronto Conference last year. The visual effectiveness of varying quantity and quality of light is applied by use of the delos method developed by Moon and Spencer,[6] and the method is extended to vision in fog and the transient case.

Because the problem is essentially a steady-state one, the simplest of the applications is to low-mounted fluorescent lighting of a turnpike. The periodic adaptation problem is confronted in the study of high-mounted street lighting. This example is the one analyzed by other methods last year by Rex.[5] Our study differs from that of Rex in that it applies the simple delos method, includes both direct and reflected glare, and is carried out for both clear weather and fog.

The runway-lighting problems are more difficult because they involve a transient state of adaptation. However, it is possible to present a considerable amount of quantitative information wtihout sacrificing simplicity. Low-mounted fluorescent flood-lighting of the runway is studied in clear weather and in fog. The effect of approach lights and of surface-mounted lights on vision at touchdown are also considered.

The most important result of the analysis of outdoor lighting by the delos method is that it gives definite guidance concerning future improvements in design.

Adaptation

If the eye is exposed for a sufficient time to a uniform visual field, every part of the retina will reach an equilibrium condition and may be said to be adapted to the uniform field. The significant characteristic of the uniform visual field in specifying the state of adaptation is the number of lumens per unit solid angle reaching the eye through a light cone which converges at the eye. This quantity has been called helios by Moon and Spencer.[7] According to the present IES definitions "brightness" is defined both in terms of a light cone diverging from the source and a light cone converging at the receiver. However, the two definitions define two distinct concepts, only one of which is of visual significance. Particular care must be exercised in the study of fog where the two definitions differ by an exponential factor.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHORS: University of Connecticut, Storrs, Conn., and Sylvania Lighting Products, Salem, Mass., respectively. Accepted by the Papers Committee as a Transaction of the IES.

In non-uniform fields, different parts of the retina may be at different adaptation levels. However, all of our critical seeing is done in a small region called the fovea, which subtends a solid angle of 1.5 degrees, Fig. 1. Throughout this paper it will be understood that the specification of the state of adaptation refers to foveal adaptation.

Non-uniform fields are said to produce the same state of adaptation as uniform fields if equivalent performance on any one of a number of visual tests such as contrast sensitivity or critical flicker frequency is obtained. The basic idea of equating a non-uniform distribution with a uniform distribution was originated by Holladay[8] in his noteworthy researches on glare. The idea has been extended by Stiles[9] and his collaborators. There is considerable evidence[9] that various visual criteria lead to the same values of adaptation helios H_A.

The adaptation helios (brightness, when defined in terms of a converging light cone) for a fixed line of sight in a non-uniform field is a weighted average of $H(\theta,\varphi)$ in the field of view, Fig. 2. The regions in or near the fovea contribute most heavily. In a uniform field the foveal region accounts for 92 per cent of the adaptation. The general equation is,

$$H_A = 0.923 H_B + \frac{9.6\,10^{-3}}{\pi} \left\{ \int_0^{2\pi} \int_{0.0131}^{1} \frac{H(\theta,\varphi)}{\ell^2} \sin\theta\cos\theta\, d\theta\, d\varphi + \sum_{i=1}^{N} \frac{H_i \cos\theta_{(\omega)i}}{\theta_i^2} \right\} . \quad (1)$$

Integration must be carried out over the entire field of view. For a continuous distribution $H(\theta,\varphi)$, the integral is evaluated, while the summation is more convenient for a set of concentrated light sources.

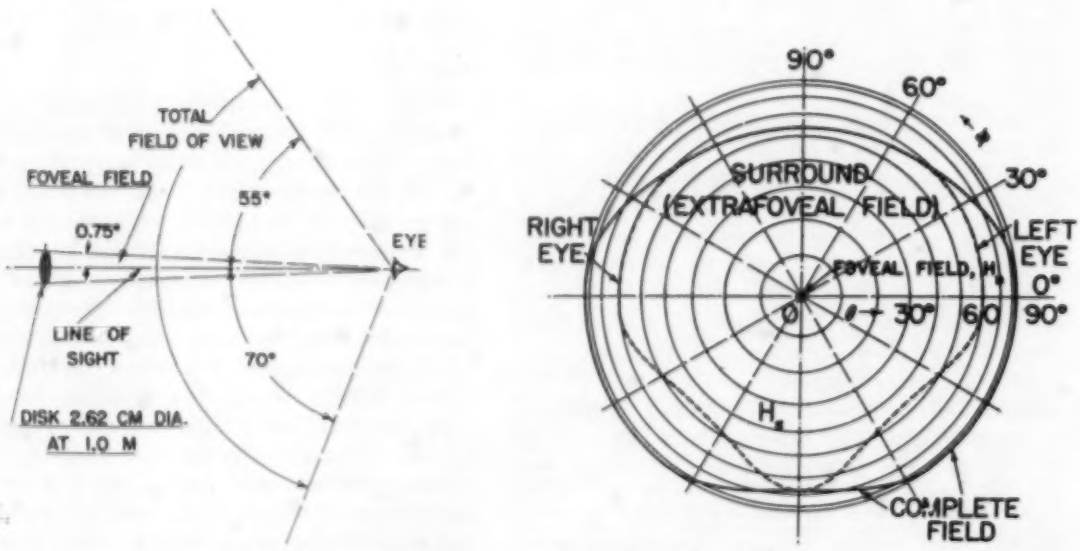
Complete specification of foveal adaptation requires knowledge of trichromatic adaptation coordinates and should also be given as a function of time. However, the single photometric measure H_A gives sufficient information except in cases of highly chromatic adaptation.[10] The transient effect should be considered. The most important characteristic of transient adaptation[11] is that light adaptation occurs very quickly, while dark adaptation is a slow process. Thus, if the extreme states of equilibrium adaptation are known in a given situation, extreme limits can be defined and it should be recognized that high adaptation levels tend to dominate in transient cases.

Contrast Data

The paper will deal with only one characteristic of vision: minimum perceptible contrast. The object to be seen subtends an angle of at least 1 degree at the eye. Assume that the background has a helios (brightness, if defined in terms of a converging light cone), H_B, as viewed by the observer and fills nearly the entire field of view while the object appears with a brightness H_O which differs slightly from that of the background. The eye adapts to the background and $H_A = H_B$. Then the minimum perceptible contrast is

$$c_{min} = \frac{(H_B - H_O)_{min}}{H_B} . \quad (2)$$

If object and background are uniformly illumi-



Figures 1a and 1b. Approximate extent of the visual field.

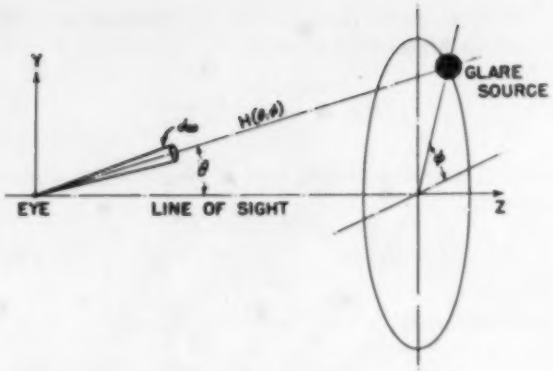


Figure 2. Concentrated glare source in the field of view.

nated, contrast may be expressed in terms of reflectance of background ρ_B and of object ρ_O as

$$c_{\min} = \frac{(\rho_B - \rho_O)_{\min}}{\rho_B}. \qquad (2a)$$

Extensive experimental data[13] from several independent laboratories (Fig. 3) can be summarized by the equation

$$c_{\min} = \frac{0.0123}{H_A} (0.808 + H_A^{1/2})^2 \qquad (3)$$

where H_A is the adaptation expressed in blondels.*

Note that the threshold contrast becomes progressively smaller, the higher the level of adaptation (if the surround is uniform). For sunlight levels, the minimum perceptible contrast is 0.0123. This means that if the background has a reflectance of $\rho_B = 0.80$, then large objects with reflectances between 0.792 and 0.808 will be invisible against it. Contrasts must equal or exceed these values if the object is to be visible.

Clear Weather Vision

The visual conditions can be evaluated by comparing the minimum perceptible contrast c at a given adaptation level with the minimum perceptible contrast c_∞ for optimum visual conditions. This ratio is called the delos based on minimum perceptible contrast (a type of relative visibility but different from "visibility" as used by Luckiesh and Moss),

$$\Upsilon = \frac{c_\infty}{c}. \qquad (4)$$

For optimum conditions $\Upsilon = 1$. But if visual conditions are imperfect $c > c_\infty$ and Υ is decreased.

If there is a uniform surround, $H_A = H_B$, the minimum perceptible contrast is c_U, and from Eq. (3) we have,

$$\Upsilon_U = \frac{c}{c_U} = \frac{H_B}{(0.808 + H_B^{1/2})^2}. \qquad (5)$$

Υ_U for uniform surround is plotted versus H_B (blondel) in Fig. 4.

If the surround is non-uniform and the adaptation H_A is raised above that of the background H_B,

*To obtain the number of blondels, multiply the number of footlamberts by 10.764.

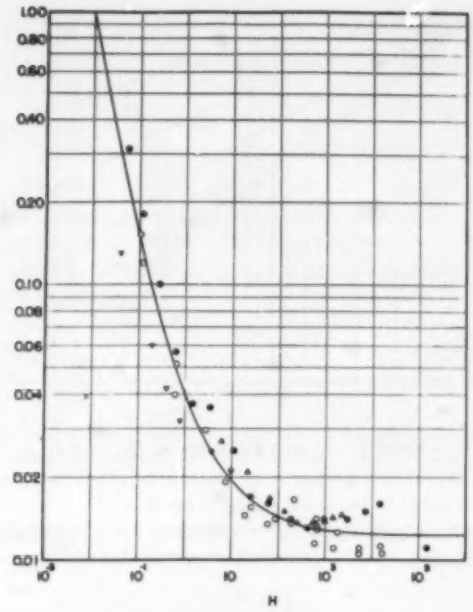


Figure 3. Minimum perceptible contrast as a function of adaptation (blondel).
○ Stiles and Crawford
△ Lowry
▽ Blanchard
● Steinhardt
— Analytic representation, Eq. 3.

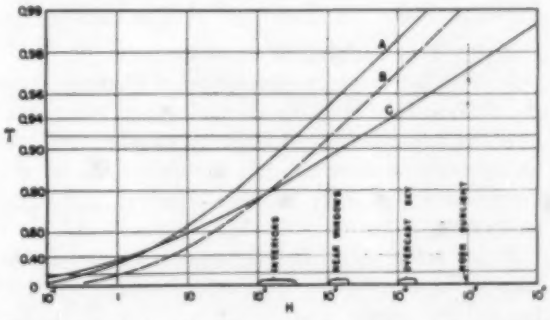


Figure 4. T as a function of helios of a uniform field (blondel).
Based on
A minimum perceptible contrast,
B single-bar test object,
C C test object.

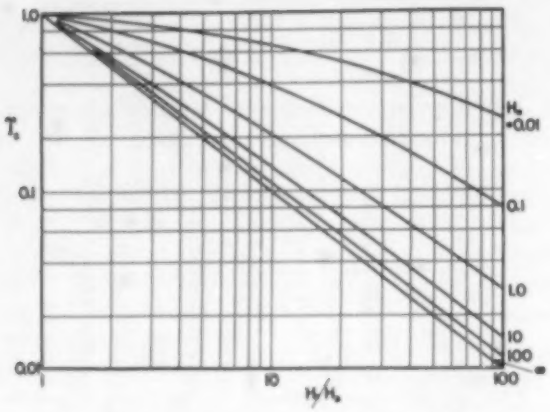


Figure 5. Υ_s as a function of H_B and H_A.

the threshold contrast is raised to c. Υ_S may be defined as

$$\Upsilon_S = \frac{c_U}{c} = \left[\frac{0.808 + H_B^{1/2}}{0.808 + H_A^{1/2}}\right]^2. \tag{6}$$

Υ_S based on minimum perceptible contrast is shown in Fig. 5.

In an actual non-uniform surround, Υ is the product of Υ_U and Υ_S.

$$\Upsilon = \Upsilon_U \Upsilon_S = \frac{c_\infty}{c_U}\frac{c_U}{c} = \frac{c_\infty}{c}$$

$$= \frac{H_B}{(0.808 + H_A^{1/2})^2} \tag{7}$$

Υ is a pure number, independent of what system of units is employed. It may be reduced below unity either by inadequate quantity of light or by glare sources which prevent the eye from adapting to the task.

Vision in Fog

In fog Υ is modified in three ways:

I. The helios of the background changes from H_B to H_{BF}. The helios H_{BF} is made up of two parts: (1) The contribution of light going directly from background to observer, (2) the helios H_{IF} of the illuminated fog layer between observer and background.

If the background has reflectance ρ_B and if the number of lumens per unit area incident on it in fog are D_F, then

$$H_{BF} = \rho_B D_F e^{-\alpha l_F} + H_{IF} \tag{8}$$

where α is the attenuation coefficient[14] in the fog per unit length and l_F is the length of the fog path.

If the entire layer of fog is illuminated with uniform heliosent[14] G, then

$$H_{IF} = \frac{G}{\alpha}[1 - e^{-\alpha l_F}], \tag{9}$$

but if only the distant part of length l_{IF} is illuminated,

$$H_{IF} = \frac{G}{\alpha} e^{-\alpha l_F}(e^{\alpha l_{IF}} - 1). \tag{10}$$

Consequently, in a uniform field in fog

$$\Upsilon_{UF} = \frac{c}{c_{UF}} = \frac{H_{BF}}{(0.808 + H_{BF}^{1/2})^2}. \tag{11}$$

In fog, it is entirely possible for H_{BF} to exceed H_B and thus for Υ_{UF} to be greater than Υ_U.

II. The adaptation in fog also changes. The integral of Eq. 1 must be re-evaluated with a suitable $e^{-\alpha l_F}$ introduced in each direction. The adaptation in fog is H_{AF} and may be much lower than H_A. Υ_{SF} in fog is

$$\Upsilon_{SF} = \frac{c_{UF}}{c_F} = \left[\frac{0.808 + H_{BF}^{1/2}}{0.808 + H_{AF}^{1/2}}\right]^2 \tag{12}$$

where c_F is the minimum perceptible helios (brightness, if defined in terms of converging light cone) contrast in fog. It is possible for c_F to be smaller than the minimum perceptible contrast in clear weather. Actually, Υ_{UF} and Υ_{SF} may be improved over clear weather values. Fog may attenuate glare sources and produce a brighter background so that the eye can perceive smaller contrasts than in clear weather.

III. The difficulty is that the contrast of all distant objects is drastically reduced by the fog. A third value Υ_{CF} is required to describe the effect of reduction of contrast in fog. Define

$$\Upsilon_{CF} = \frac{c_F}{c} \tag{13}$$

where

$$c_F = \frac{H_{BF} - H_{OF}}{H_{BF}}$$

(the contrast for an object and background viewed in fog at distance l_F) and c is the contrast of ob-

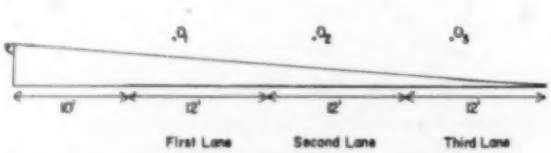


Figure 6. Turnpike configuration of low-mounted fluorescent luminaires. Driver's eyes are assumed to be at 0_1, 0_2, and 0_3 in first, second, and third traffic lanes.

ject and background viewed at $l_F = 0$. If background and object are uniformly illuminated

$$c = \frac{\rho_B - \rho_O}{\rho_B}$$

and

$$c_F = \frac{(\rho_B - \rho_O)\, D_F\, e^{-\alpha l_F}}{\rho_B D_F\, e^{-\alpha l_F} + G\, l_{IF}}$$

or

$$\Upsilon_{CF} = \frac{\rho_B\, D_F\, e^{-\alpha l_F}}{H_{BF}}. \qquad (14)$$

The over-all delos in fog is Υ_F,

$$\Upsilon_F = \Upsilon_{UF}\, \Upsilon_{BF}\, \Upsilon_{CF} = = \frac{c_\infty}{c_{UF}} \frac{c_{UF}}{c_F} \frac{c_F}{c} = \frac{c_\infty}{c} \qquad (15)$$

$$\Upsilon_F = \frac{\rho_B\, D_F\, e^{-\alpha l_F}}{(0.808 + H_{AF}^{1/2})^2}. \qquad (16)$$

In fog, Υ_F depends both on the attenuation coefficient in the fog and on the distance d at which we are trying to see a given detail of inherent contrast c. Thus we can plot Υ_F versus d and determine the distance d at which a chosen contrast c can just be perceived.

Adaptation on Turnpike

Low-Mounted Fluorescent

The simplest of the examples to be considered here is the turnpike lighted by an infinitely long strip of low-mounted fluorescent lighting.[2] Luminaires are mounted in the center strip of the turnpike with theoretical cut-off plane tilted downward so that it intersects the roadway at the far side of the road. The values given in Table I for clear weather are based on calculations from the foregoing equations and on measured values of the helios of black asphalt pavement and luminaire as a function of angle. An equivalent diffuse reflectance (Fig. 7) was measured in an actual installation and is used here in place of the more refined techniques that are anticipated[1] in the future. In clear weather it is assumed that the line of sight of the driver is parallel to the line of luminaires.

Table I shows that the cut-off in the luminaires measured is sufficiently sharp so that Υ_g is always between 0.977 and 0.924. Υ is never reduced more than 8 per cent by non-uniformity in the field of view if it is assumed that the driver always keeps his eyes fixed on a distant part of the road. In clear weather Υ is 0.546 even in the third lane and reaches 0.785 in the first lane.

Calculations of Υ_F in fog as a function of the distance d were also made. Here d is the distance ahead of the driver at which an object of contrast c is to be seen. In this work, extensive use was made

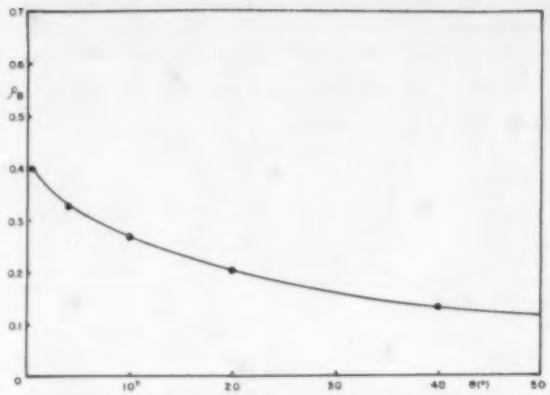


Figure 7. Equivalent diffuse reflectance of black asphalt pavement illuminated by low-mounted fluorescent at Washington National Airport as a function of angle of view. Angle θ is measured below horizontal in vertical plane parallel to luminaires. Measurements by Tom Lemons of Sylvania Electric Products.

of previous calculations[14] of fog on turnpikes. Three fogs are considered:

Light turnpike fog, $\alpha = 3.28 \times 10^{-2}\ m^{-1} = 10^{-2}\ ft^{-1}$,

Medium turnpike fog, $\alpha = 1.640 \times 10^{-2}\ m^{-1} = 5 \times 10^{-2}\ ft^{-1}$,

Thick turnpike fog, $\alpha = 3.28 \times 10^{-1}\ m^{-1} = 10^{-1}\ ft^{-1}$.

These attenuation coefficients correspond to meteorological visual ranges of 91.6 meters (300 feet), 18.3 meters (60 feet), 9.16 meters (30 feet).

The results are summarized in Table II and Fig. 8. A Υ of 10 per cent means that the minimum perceptible contrast is still 0.123. Thus, for a background reflectance of 0.40, a marking of reflectance 0.35 or 0.45 would still be just visible.

These visual conditions are retained in the first

TABLE 1—Clear Weather Vision on Turnpike — Low-mounted Fluorescent.

	Lane 1	Lane 2	Lane 3
D (on horizontal surface)	128.2 lumen m^{-2} (11.92 lumen ft^{-2})	38.0 lumen m^{-2} (3.54 lumen ft^{-2})	18.00 lumen m^{-2} (1.672 lumen ft^{-2}
D (on vertical back of truck)	199.4 lumen m^{-2} (18.54 lumen ft^{-2})	108.8 lumen m^{-2} (10.10 lumen ft^{-2})	74.9 lumen m^{-2} (6.96 lumen ft^{-2}
H_B (blondel) (black asphalt pavement)	51.3	15.22	7.19
T_U	0.804	0.683	0.591
H_A (blondel)	52.7	16.18	7.91
T_g	0.977	0.953	0.924
T	0.785	0.651	0.546

TABLE II—Vision in Fog on Turnpike—Low-mounted Fluorescent.

d (foot)	$\alpha = 10^{-3}$ ft^{-1}	Υ_F $\alpha = 5 \times 10^{-3}$ ft^{-1}	$\alpha = 10^{-1}$ ft^{-1}
First Lane			
200	0.0748	1.812×10^{-4}	.....
150	0.1131	1.289×10^{-3}	.....
100	0.1800	8.72×10^{-3}	.....
80	0.220	0.01812	.....
60	0.274	0.0382	3.84×10^{-3}
40	0.347	0.0812	0.01708
20	0.447	0.1709	0.0700
10	0.492	0.243	0.1330
Second Lane			
200	0.0762	1.290×10^{-4}	.....
150	0.1131	1.142×10^{-3}	.....
100	0.1631	8.14×10^{-3}	.....
80	0.1942	0.01688	.....
60	0.236	0.0340	1.432×10^{-3}
40	0.288	0.0863	7.51×10^{-3}
20	0.356	0.1261	0.0322
10	0.382	0.1658	0.0577
Third Lane			
200	0.1042	4.20×10^{-5}	.....
150	0.1417	4.77×10^{-4}	.....
100	0.1967	4.72×10^{-3}	.....
80	0.225	0.0110	.....
60	0.259	0.0240	.....
40	0.299	0.0516	1.718×10^{-3}
20	0.336	0.0920	5.87×10^{-3}
10	0.332	0.1465	0.01582

lane at 165 feet in light fog, at 35 feet in a medium fog, and even in a dense fog at 15 feet. In the second lane Υ_F of 0.10 is obtained at 165 feet in a light fog, at 28 feet in a medium fog. In the third lane visual conditions are better in a light fog because the brightness of the illuminated fog is much less than in the other lanes. Here $\Upsilon_F = 0.10$ holds at 200 feet in a light fog and at 18 feet in a medium fog. If a value of $\Upsilon_F = 0.10$ is taken as a criterion for keeping the traffic lanes open, then traffic can move at high speed in all three lanes in light fog, at restricted speeds in a medium fog, and at low speeds in the inside lane even in very dense fogs. Correlation of Υ_F at a given distance with safe speeds for traffic would be valuable.

TABLE III—Clear Weather on Turnpike—High-mounted Incandescent. (Average of 1.3 lumen ft^{-2})

	Best Visual Conditions	Worst Visual Conditions
Without Reflected Glare (including direct glare from luminaires)		
H_B (blondel)	7.75	3.44
Υ_U	0.600	0.487
H_A (blondel)	7.96	4.68
Υ_S	0.980	0.802
Υ	0.587	0.390
With Reflected Glare (from one luminaire reflected in hood of car, $\rho_g = 0.04$)		
H_A (blondel)	81.5	77.1
Υ_S	0.1252	0.0768
Υ	0.0752	0.0374

High-Mounted Incandescent

As an alternative method of turnpike lighting, consider that employed in an example in an earlier paper[5] by Rex. The detailed presentation given by Rex was very helpful in making the calculations described in Table III and Fig. 9. A Type III incandescent street luminaire is employed on a six lane highway with 120-foot staggered spacing. As one drives down the road, he periodically encounters very good visual conditions: $\Upsilon_S = 0.980$ and $\Upsilon = 0.587$, which is slightly higher than that obtained in the third lane in Table I. At its best, in clear weather, the high-mounted incandescent system described here gives visual conditions similar to the visual conditions in the most unfavorable traffic

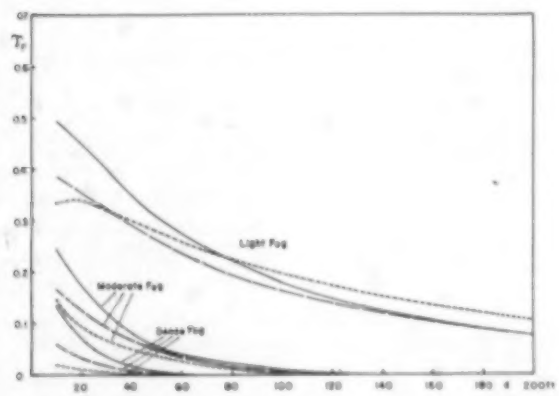


Figure 8. Υ_F in fog on turnpikes with low-mounted fluorescent luminaires.
—— First traffic lane,
— — Second traffic lane,
····· Third traffic lane.

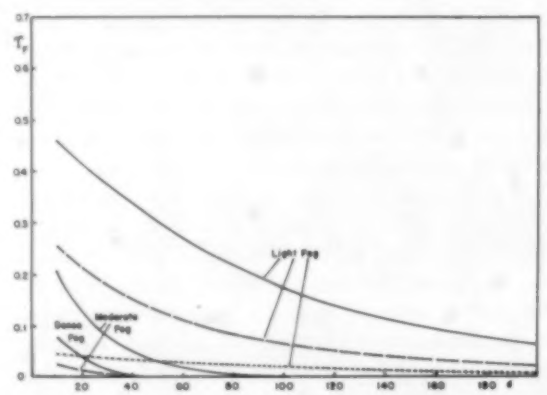


Figure 9. Υ_F in fog on turnpikes with high-mounted incandescent luminaires.
—— Best visual conditions,
— — Worst visual conditions without reflected glare,
····· Visual conditions with reflected glare.

lane with low-mounted fluorescent. But here the visual conditions are not constant. They are aggravated by fluctuating variations in the state of adaptation of the eye. The direct effect of the overhead luminaires is to reduce Υ_g to 0.8 every few feet. And because of the swiftness of light adaptation, the tendency will be for this value to dominate. The deleterious effect of the overhead lighting is not completely described by the foregoing. For nearly all automobiles have hoods which are finished with a high gloss surface. The hood of the car is an unavoidable source of reflected glare in any high-mounted system. Suppose that there is only one luminaire reflected in the hood and that the driver involuntarily glances at it long enough to become adapted. Then Υ_g drops to about 1/10 of its previous value and Υ is always less than 0.10. Thus, under actual driving conditions, with reflected glare considered, Υ for high-mounted luminaires in clear weather is lower than that for low-mounted luminaires in serious fogs.

Calculated results in fog with high-mounted incandescent are given in Table IV and plotted in Fig. 9. Even in a light fog, conditions for driving are not satisfactory. As one moves along the road the distance at which $\Upsilon_F = 0.10$ oscillates from 67 to 152 feet if reflected glare is eliminated but is reduced to less than 10 feet if reflected glare is taken into account. Thus, it would appear that a value of $\Upsilon = 0.10$ cannot be sustained even in a light fog. In a medium fog, the optimum conditions give $\Upsilon_F = 0.10$ at 25 feet. But the periodic minima of Υ, which will dominate the transient adaptation, are only 0.02 even at 10 feet. It is noteworthy that the medium fog is so dense that even the reflected glare has become negligible. In a dense fog the higher value of Υ_F is nearly 0.08 at 10 feet but the dominant minima are now 0.002. Consequently, this analysis leads to the conclusion that a value of $\Upsilon = 0.10$ cannot be sustained in any of the three fogs.

The difficulty with overhead lighting in fog is threefold: (a) The entire fog layer is illuminated, (b) Direct glare from luminaires is periodically appreciable, (c) Reflected glare from automobile hood and interior of car is a major source of reduction in ability to see fine details. The advantages of low-mounted fluorescent depend on the existence of a sharp cut-off plane. Any possible modifications in the design of low-mounted fluorescent lighting which will reduce the helios of the luminare above the theoretical cut-off plane are of great importance.

Adaptation on Runway

The pilot approaches the runway along the glide path shown in Fig. 10. Adaptation will be studied at four points along the glide path:

A. Over the first approach light, 3000 feet from the edge of the runway. Here the height of the pilot above the runway level is 183.0 feet. Line of sight is directed along the glide path sloping 2.8 degrees below horizontal.

B. Over the 1000-foot bar at a height of 85.2 feet. Line of sight is along glide path.

C. At edge of runway at height of 36.4 feet.

D. At touchdown 50 feet from edge of runway. Pilot's eyes are 12 feet above runway.

TABLE IV—Vision in Fog on Turnpike—High-mounted Incandescent.

d (ft)	Υ_F $\alpha = 10^{-3}$ ft^{-1}	$\alpha = 5 \times 10^{-3}$ ft^{-1}	$\alpha = 10^{-1}$ ft^{-1}
Best Visual Conditions (minimum direct glare, no reflected glare)			
200	0.0613	1.637×10^{-5}	.....
150	0.1022	1.982×10^{-4}	.....
100	0.1748	2.42×10^{-3}	.....
80	0.216	6.58×10^{-3}	.....
60	0.266	0.01805	.....
40	0.333	0.0482	6.27×10^{-3}
20	0.411	0.1271	0.0384
10	0.457	0.204	0.0776
Worst Visual Conditions			
A. Without reflected glare			
200	0.0210	1.310×10^{-5}	.....
150	0.0363	1.589×10^{-5}	.....
100	0.0659	1.940×10^{-4}	.....
80	0.0840	5.32×10^{-4}	.....
60	0.1117	1.471×10^{-3}	.....
40	0.1518	4.19×10^{-3}	.....
20	0.212	0.01290	.....
10	0.255	0.0249	1.788×10^{-3}
B. With reflected glare			
200	0.00590	1.188×10^{-5}	.....
150	0.00985	1.445×10^{-5}	.....
100	0.01655	1.762×10^{-4}	.....
80	0.0205	4.85×10^{-4}	.....
60	0.0254	1.332×10^{-3}	.....
40	0.0314	3.77×10^{-3}	.....
20	0.0391	0.01137	.....
10	0.0439	0.0212	1.775×10^{-3}

Steady Approach Lights

Calculations were made of the state of adaptation produced by the steady approach lights (configuration "A") at points A and B. Table V gives the calculated results. These are the values of adaptation which would be attained if the pilot stayed still at a given point on the glide path long enough to become fully adapted. Calculations are given for two settings of the approach lights. On Step 2, the axial candlepower is 200. This is the clear weather beam. Thus, if the pilot comes in on a clear night, his adaptation at point A is 0.12 blondel and at B

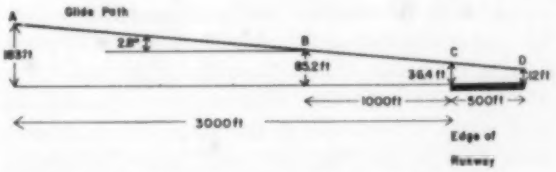


Figure 10. Glide path approaching touchdown on runway at point D.

TABLE V — State of Adaptation Produced by Steady Approach Lights.

	H_A (blondel)			
	Clear Weather	$\alpha = 10^{-3}$ ft^{-1}	$\alpha = 5 \times 10^{-3}$ ft^{-1}	$\alpha = 10^{-2}$ ft^{-1}
Point A Step 2	0.1200	0.0206	4.24×10^{-5}	4.93×10^{-6}
Step 3	0.599	0.01032	2.12×10^{-4}	2.46×10^{-7}
Point B Step 2	0.1420	0.176	0.01168	1.380×10^{-3}
Step 3	0.711	0.475	0.0584	6.91×10^{-4}

rises slightly to 0.14 blondel (or from 0.011 footlambert to 0.013 footlambert). As the pilot has travelled a considerable distance with this state of adaptation, when he comes to points C and D his adaptation will remain nearly as high as the calculated values at points A and B.

Calculations were also made in fog using the methods outlined in a previous paper.[15] On the runway the most dense fog considered has the same attenuation coefficient as the light turnpike fog. Three fogs are studied:

Light runway fog, $\alpha = 3.28 \times 10^{-3}\ m^{-1} = 10^{-3}\ ft^{-1}$,

Moderate runway fog, $\alpha = 1.64 \times 10^{-3}\ m^{-1} = 5 \times 10^{-3}\ ft^{-1}$,

Thick runway fog, $\alpha = 3.28 \times 10^{-2}\ m^{-1} = 10^{-2}\ ft^{-1}$.

These correspond to meteorological visual ranges of 916 meters, 183 meters and 91.6 meters or 3000 feet, 600 feet and 200 feet. It is customary to operate the steady approach lights at Step 3 in fog. Because the distance to the approach lights is much smaller from position B than from position A, there is now a considerable difference between the adaptations at the two positions. For this investigation, the significant question is whether the adaptation determined by the approach lights differs significantly from the brightness of the runway surface as viewed by the pilot.

Low-Mounted Fluorescent

Luminaires[2] of the same type as described in the low-mounted turnpike application are mounted along the edge of the runway.[15] In the calculations the luminaires are assumed to extend infinitely far ahead of the edge of the runway. The pilot is assumed to travel down the center of the runway with his line of sight along the glide path. Table VI gives results for points C and D on the glide path for a 150-foot and a 200-foot runway. Even though the equivalent reflectance of the pavement is higher here than in the turnpike case (since both light sources and line of sight are at near grazing angles) the values of Υ_V are substantially lower than on the turnpike. We have values of 0.352 on the narrow runway and 0.272 on the wide runway.

TABLE VI — Clear Weather Vision on Runway—Low-mounted Fluorescent.

	150 Foot Runway		200 Foot Runway	
H_B (blondel) (black asphalt pavement)	1.378		0.775	
T_V	0.352		0.272	
	Point C	Point D	Point C	Point D
H_A (blondel) (including effect of low-mounted luminaires)	1.487	1.810	0.888	1.397
T_S	0.952	0.847	0.928	0.752
Υ	0.335	0.298	0.252	0.204

As there is some light spilled above the cut-off plane, Υ_S, which is above 90 per cent in position C, falls to values of 0.847 and 0.752 in position D. In Table VI the final values of Υ are between 0.20 and 0.33 at the center of the runway in clear weather. These values could be substantially improved by using brighter light sources and by decreasing the amount of light spilled above cut-off.

Comparison of the values of H_A in Tables V and VI shows that the approach lights, if operated on Step 2 in clear weather never reduce Υ_V by more than 6 per cent. Thus, the approach lights do not appreciably alter the state of adaptation in clear weather.

Calculations of the delos on the runway at position C were also made, using data of an earlier paper.[15] The results are shown in Table VII and Fig. 11. The delos in a light fog is 0.10 at 650 feet on the 150-foot runway and at 250 feet on the 200-foot runway. However, the delos required for safe landing with information on texture gradients is probably much below 0.10.

TABLE VII — Vision in Fog on Runway—Low-mounted Fluorescent.

d (Feet)	T_V $\alpha = 10^{-3}$ ft^{-1}	$\alpha = 5 \times 10^{-3}$ ft^{-1}	$\alpha = 10^{-2}$ ft^{-1}
150-Foot Runway			
3000	0.01857	2.14×10^{-7}	.....
2500	0.0258	2.58×10^{-6}	.....
2000	0.0360	3.10×10^{-5}	.....
1500	0.0507	3.36×10^{-4}	1.310×10^{-7}
1000	0.0742	3.06×10^{-3}	1.850×10^{-5}
750	0.0906	7.80×10^{-3}	2.02×10^{-4}
500	0.1143	0.01862	1.878×10^{-3}
250	0.1453	0.0424	1.231×10^{-2}
200-Foot Runway			
3000	0.01857	2.14×10^{-7}	.....
2500	0.0258	2.58×10^{-6}	.....
2000	0.0360	3.10×10^{-5}	.....
1500	0.0507	3.36×10^{-4}	1.310×10^{-7}
1000	0.0742	3.06×10^{-3}	1.850×10^{-5}
750	0.0906	7.80×10^{-3}	2.02×10^{-4}
500	0.1143	0.01862	1.878×10^{-3}
250	0.1453	0.0424	1.231×10^{-2}

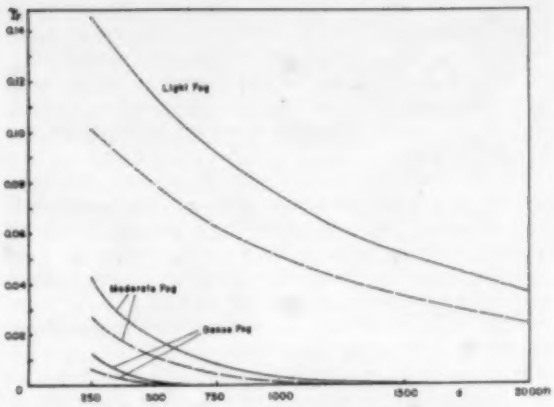


Figure 11. T_p in fog on runway with low-mounted fluorescent luminaires floodlighting runway.
—— Center of 150-foot runway,
— — Center of 200-foot runway.

Now consider the effect of steady approach lights at Step 3. In light fog (Table V), the adaptation may be raised by 0.475 blondel (0.044 footlambert). How does this compare to the state of adaptation produced by the floodlighting itself? For the 200-foot runway the adaptation varies from 0.489 blondel at 3000 feet to 1.189 blondel at 750 feet. The steady approach lights may thus increase the state of adaptation by 50 to 100 per cent and will thus produce a serious reduction in ability to see surface texture on the runway if operated at Step 3. In a medium fog, these approach lights would double the state of adaptation at 1000 feet; and in a dense fog would double it at 750 feet. In addition the approach lights illuminate a thick layer of fog. This illuminated fog layer serves merely to blanket the runway with a bright veil. Thus, we can conclude that operation of the steady approach lights at customary levels can seriously interfere with pilot information on surface detail. If the most significant pilot information can be conveyed by recognition of runway markings and textural gradients, then the approach lights should be operated at lower than customary levels.

Surface Mounted Lights

Various configurations of surface-mounted lights have also been proposed. These vary from a powerful array of flush mounted lights in a narrow gauge formation to small surface-mounted lights on the centerline. As the button-type lights could be used in conjunction with runway floodlighting to provide emphatic centerline guidance, let us consider the advisability of such a step.

Consider a pilot at position D. Assume his line of sight is 15 degrees below horizontal. Then the adaptation for the button lights is 20.56 blondel (1.91 footlambert) in clear weather, 19.67 blondel (1.83 footlambert) in light fog, 16.28 blondel (1.51 footlambert) in moderate fog, and 12.93 blondel (1.20 footlambert) in thick fog. These values are many times higher than the helios of the runway. In clear weather, the button lights raise the adaptation by a factor of 16.9 on the 200-foot runway and reduce the delos from 0.204 to 0.0257. Thus, the button lights in clear weather reduce the value of Υ as much as does a moderate fog at 500 feet. In fog similar decreases in Υ occur. These calculated reductions in delos are correlated with the pilot's comment[16] that the lights cause "some target fascination and I had to glance to the side to judge height."

According to pilots,[16] the surface mounted lights are "very poor for height and attitude perception during final stages of landing" and "made it appear we were higher than actual during round out." The pilots also indicate[16] that if the lights are at the brightest setting in clear weather "they tend to stand out above the surface of the pavement."

Other comments indicate that even with a bright centerline pilots are attempting to see the runway surface and the edges of the runway are of great importance: "concrete surface is far superior to blacktop in providing height perception" and "two rows of lights along the edge of the runway are of far greater aid than the single row down the middle of the runway."

Apparently, adequate information is not given to the pilot from an array of lights in the center of the runway. For accurate location of the runway surface, the entire surface must be illuminated so that textural gradients[17] and markings can be seen as in daylight.

To obtain even better visual conditions for landing the procedure needed is:

(1) To increase the helios of the light source by as large a factor as possible,

(2) To eliminate all possible stray light above the theoretical cut-off plane,

(3) To operate approach lights at low levels which will not appreciably interfere with adaptation to runway detail and will illuminate the fog as little as possible.

In conclusion, we wish to thank L. L. Montgomery of Sylvania Electric Products, Inc. for his faithful assistance in the calculations.

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DISCUSSION

SYLVESTER K. GUTH:* As is usually the case, a paper with which Dr. Spencer is associated has some very interesting implications and possibilities. Unfortunately, I am afraid not too many people will take the time to read it, being discouraged, perhaps, by some of the nonstandard terminology and mathematics. Nevertheless, it is worth a careful study because it does contain some valuable suggestions for evaluating the effect of nonuniformities of brightness in the visual field.

The proposed method is not new; Moon and Spencer first suggested it some 15 years ago. Earlier, Reid and Chanon developed a procedure and instrumentation for evaluating the effect of disability glare. More recently, Blackwell has used his fundamental threshold data in a similar manner. Many others, in this country and abroad, have devoted considerable time and effort to this problem. Incidentally, all three editions of the *IES Lighting Handbook* have contained a brief outline of how to deal with the effects of bright sources upon ability to see. In other words, many efforts have been directed toward the development of a simple and practical method for appraising seeing on a lighted roadway. Much information still is needed. Perhaps some of the current researches sponsored by the IERI will help fill the gaps.

Stated simply, the authors rate the minimal detectable contrast in a given situation — with or without glare and with or without fog — in terms of the minimal detectable contrast under optimum daytime visual conditions. They are computing the veiling effect produced by bright areas surrounding the object which must be seen. The ratio, or relative visibility (delos), can be considered a measure of the efficiency of seeing based upon contrast. Of necessity, it is an evaluation of a static condition, even though ratings can be computed for various positions along a roadway or glide path. However, many other factors involved in the usual dynamic situation should also be considered, such as the driving speed which influences the duration and frequency of values of H_A and H_B, eye movements towards other portions of the visual field, approaching headlights (even on turnpikes), silhouette *vs* direct seeing of objects, typical distractions, etc.

In Fig. 4, what is the significance to the present discussion of the curves labeled *B* and *C*? On Fig. 5, what does the subscript *C* on upsilon represent? How do Blackwell's new threshold data fit in with those shown in Fig. 3?

I doubt that the value of relative visibility as given by Eq. (7) is quite as pure as the authors indicate. Its absolute value is very much dependent upon the units used.

The comparison of the two roadway lighting systems in clear weather results in the obvious conclusion that a higher roadway brightness results in better seeing. The differences in relative visibility appear to be attributable primarily to this factor. For the fog conditions, it appears that the loss with the high-mounted incandescent system is considerably less than that with the low-mounted fluorescent system. It would be interesting to have the results for equal values of H_B—*i.e.*, reduce H_B for the low-mounted fluorescent system to the same value as for the high-mounted incandescent system.

In our country, the usual practice is to drive in the right lane (lane No. 3) except when passing. What would be the effect, for example, of moving fairly rapidly from lane 1 to lane 3, with H_A decreased from 52.7 to 7.9 blondels?

The example of reflected glare assumes direct fixation of the image of the source long enough to become adapted to it. This presupposes that the car is standing still for such a period of time. What about the situation while moving at normal turnpike speeds? In such practical situations, the reflected image would move across the lower portion of the visual field too rapidly to be fixated. Thus, it would be rather difficult, and potentially hazardous, for the driver to try to become adapted to this reflection. Would the curvature of the hood have any significant effect upon the brightness and size of the reflected image?

The authors state that the relative visibility method is simple. While the basic concept is simple, its application seems to be relatively complex and tedious to work out. However, this is common to all such computations.

None of this is intended to deprecate in any way the efforts of the authors. They are to be commended for reviving the Moon and Spencer "visual effect of nonuniform surrounds" and applying it to these outdoor seeing situations. However, what we really need is a method for relating these static evaluations to typical dynamic conditions.

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HAROLD F. WALL:* The statement that "the engineering of outdoor lighting has generally neglected the state of adaptation of the eye" of course is not correct. The Roadway Lighting Committee has spent much time and effort designating easily measured parameters and limits for street lighting so that following the Standard Practice would ensure effective and comfortable installations, but they are fully aware of eye adaptation as well as the many other facets of visibility.

At the Toronto Conference the authors recommended four fixtures mounted 18 feet high and at a spacing of 110 feet along the medial strip on Detroit turnpikes. Now they recommend a continuous line of luminaires mounted below windshield height. The cost of such an installation would seem excessive.

We question the possibility of as sharp a cutoff as that assumed by the authors from a luminaire using a one-and-a-half-inch diameter lamp. We now have some of these luminaires and the cutoff is not as assumed. This would seem to change the authors' conclusions.

Comments from the authors on the following questions would be appreciated:

First: What is going to be the effect on visibility of a specular pavement such as after or during a rainstorm? In most parts of the United States there are more rainstorms than there are fogs, so that specular reflection becomes very important.

Second: How do you get light on the fourth lane of a four-lane roadway when you have bumper-to-bumper traffic on all four lanes, which is not at all uncommon on turnpikes in Detroit and San Francisco?

Third: How effective would this type of lighting be on exit ramps, interchanges, etc., where it has been definitely proved that it isn't only pavement brightness which you are interested in but also area illumination?

Fourth: Speaking of area illumination, I personally am still of the opinion that lighting the pavement alone may be all right under fog conditions, but in general any roadway lighting system which only lights the pavement falls down hopelessly because the driver wants to see the surround—he wants to see the size and shape of objects in front of him, and with low-mounted units cut off as indicated, trucks, busses, cars and other types of vehicles would only show those parts which are below the cutoff point, and might confuse rather than aid in over-all visibility.

Fifth: What kind of maintenance problems could be expected, since these luminaires will be exposed to traffic spray and might be covered by snow in winter?

C. H. REX:** Dr. Spencer and Mr. Peek have presented an excellent paper. We welcome their computations of the relative visibility of a roadway lighting system in terms of "delos, based upon minimum perceptible contrast (a type of relative visibility but different from 'visibility' as used by Luckiesh and Moss)." Thus, their paper provides a correlation between two different methods of rating the effectiveness of a roadway lighting system. Such correlations are constructive and should be extended to include other proposed methods of using and combining the brightness data provided under representative roadway lighting conditions.[1,2,3]

Upon further study the authors will find that the engineering of outdoor lighting has not neglected the adaptation of the eye to the extent that they apparently believe. We have also stressed the need for increased attention to the transitory conditions of brightness and visibility.

The authors might well expand their evaluations of the adaptation of the driver's eyes under representative dynamic night-driving conditions. For example, how extensively do maximum brightness conditions persist, as a prevailing residual condition, when driving 50 or 60 miles per hour? How much safety factor, extra visibility, etc., must be provided to offset such a condition?[4] Comments or conclusions regarding the effect of brightness conditions in the extra-foveal field illustrated in Fig. 1 will be welcomed.

We note that "the object to be seen, or target, subtends an angle of at least one degree at the eye" in a visual field of 1.5-degree solid angle. Experience in actual measurements does indicate that the target is discerned by contrast with the highest, or lowest, *adjacent* brightness (for silhouette and reverse silhouette discernment respectively).

What instrumentation would the authors suggest to supplement their computations?

Low-mounting-height roadway lighting has long been of interest to a number of us; one example of such interest is my discussion of Richard G. Slauer's 1949 IES paper on this subject.[5] These comments ten years ago suggested evaluation of low-mounting-height lighting on the basis of visibility and seeing comfort per dollar annual cost. An experimental installation of low-mounting-height lighting was made near the Wellington Bridge at Somerville, Massachusetts for investigation and appraisal by the Massachusetts Highway Department. The 2400-foot length of rail lighting[3] recently installed on the Manahawkin Bay Bridge by the New Jersey Highway Department has generated considerable interest.

It is hoped that the authors will continue their good work in evaluating the effectiveness of roadway lighting. Their generous recognition of my papers is appreciated.

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D. M. FINCH:* This is indeed a profound paper in modern Greek. The delos method is still as mysterious as the machinations of Hecate, the Greek Goddess whose presence I seem to feel as I study the paper.

The analysis is specifically limited to foveal adaptation using 1.5 degrees as the total plane angle of the fovea. In addition, minimum perceptible contrast is used as the visual criterion and the object must subtend at least one degree at the eye. For the range of adaptation brightnesses from sunlight to 0.001 footlambert the minimum perceptible contrast ranges from 0.0123 (what precision!!) to 1.00. The use of the above values are all subject to discussion. The foveal region is not a precise area, is not equally sensitive over its entire surface and probably is not 92 per cent effective in determining adaptation, as claimed. Suppose for example, one looked at a uniform field with a 1.5-degree hole in the center. Would the adaptation be largely that of the

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hole? Probably not. The values for M.P.C. are good for the laboratory conditions under which they were determined. The values shown may not be the best to use for roadway studies. More recent work should probably be considered.

The use of minimum perceptible contrast data alone for the runway or roadway situation hardly seems appropriate as a means of specifying the adequacy of the visual environment. One can develop many practical situations wherein the minimum perceptible contrast may be poor compared to the best value that might be achieved, yet the total environment may be quite good. For example, in landing an airplane at night, the pattern of the light sources in the vicinity of the runway provides most of the information required by the pilot. The minimum perceptible contrast of large objects in the runway may be poor but it is not too important until the last phases of landing are encountered and even then the pilot has little need to see details on the runway surface.

The fog problem does require a special analysis. The treatment of dark objects against a lighter background can be handled in the manner illustrated. Self-luminous objects, such as light sources, will require a different treatment since there is usually a substantial forward scattering effect.

The high-mounted *vs* low-mounted luminaire argument is interesting and full of explosive fuel. The point to make is that a desirable lighting condition is one in which a uniform pavement brightness is achieved with reasonable freedom from glare. It is possible to achieve this result with either system.

The comments on the surface-mounted lights are unfortunate. The conclusions seem to be entirely wrong and are probably due to the assumption, "For this investigation, the significant question is whether the adaptation determined by the approach lights differs significantly from the brightness of the runway surface as viewed by the pilot." Why see the *surface*? Guidance in landing is the important thing.

The authors show that the button lights on the centerline have adaptation brightnesses of 1.9 footlamberts in clear weather, 1.5 footlamberts in moderate fog and 1.2 footlamberts in thick fog. If this is true, the lights function exactly as desired with very little attenuation due to fog. It is not intended or necessary for the pilot to see the surface. It is only necessary to have the plane of the surface clearly defined to permit touchdown at the desired location.

The authors took the liberty of extracting a few pilot comments on the subject of the centerline system from many included in a recent report to the F.A.A. I prefer to select others. For instance: "Good idea; definite improvement; general impression very good; damn good; believe centerline lights are improvement over centerline paint mark; very easy to accomplish smooth landing by concentrating on centerline lights."

P. W. Smith:* The comparison of low- *vs* high-mounted turnpike lighting equipment in producing reflected glare raises one question.

In discussing the low-mounted system the authors assume that "the driver always keeps his eyes fixed on a distant part of the road." Assumptions are necessary in any experiment, and this is a good one.

However, in discussing the high-mounted system the authors suggest that "The hood of the car is an unavoidable source of reflected glare . . . and that the driver involuntarily glances at it. . . ."

In an examination of turnpike lighting, we can not avoid the consideration of more than one automobile. My question then is: Would not reflected glare from adjacent automobile surfaces, as produced by a low-mounted system, be equally or perhaps even more deleterious than the same effect from a high-mounted system?

In their discussion of runway lighting, the authors make reference to an illuminated fog layer blanketing the runway with a bright veil, when lighted by conventional steady approach lights. It appears that this same veiling condition would manifest itself with low-mounted fluorescent luminaires and, perhaps, even produce the effect of a false surface above the actual runway surface and at the cutoff plane of the luminaire.

Assuming that floodlighting of a runway produces adaptation and performance as presented, it appears that we must go further.

Today's aircraft often leave the runway and taxi at speeds in the neighborhood of 60 mph. With a floodlighting system, as described, it appears that it would be necessary for taxiways to be equally lighted. Otherwise a pilot would be completely blind at the time of exit.

These arguments on adaptation are good ones. However, history presents what must be practical considerations. In 1929 the first floodlighting system was installed at Hoover Airport in Washington, D. C. It was removed after a mail plane crashed in the fog. A Fresnel incandescent system installed in 1934 at St. Louis lasted two years. In 1939 a cold cathode fluorescent system at St. Louis survived only one season.

I suspect that until we can completely floodlight an airport area, the systems of producing signals—rather than illumination—will, for both reasons of economy and adaptation, prevail.

H. R. Blackwell:* Let me begin by stating my complete agreement with the emphasis the authors have placed upon analyzing all visual factors involved in roadway and runway lighting, rather than concentrating upon illumination levels alone.

What the authors have done is to use a relative contrast value (which they call delos) to specify the visual effects of the brightness level, the disability glare, and the presence of fog as a contrast reducer. These indices are multiplied to provide an over-all index of visibility, thus providing a means of computing the over-all effect of various illumination systems in outdoor visibility problems. This can also be achieved by computing the brightnesses and the contrast reduction produced by fog, then allowing for the disability glare produced by luminaires as modified by fog, and finally computing the threshold contrast under these conditions.

The difference in results obtained by the two methods will depend primarily upon the performance data used in the two cases. The authors use data resulting from indefinite exposures of large test objects rather than performance data collected with controlled exposures, which is unfortunate. For consistency, it would be nice if the authors used the performance data used by IES in the Blackwell system although the important point is that the authors should use data obtained with short exposures since these are the conditions of most practical seeing.

I suggest that empirical tests of outdoor lighting are important because (a) the authors ignore secondary scatter by the atmosphere, and (b) they ignore the important effects of non-uniformity of visual backgrounds other than the disability glare effect.

I share the authors' concern for transient adaptational

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effects. However, we don't know enough yet to provide a basis for computation. If anything, the effects are more important than the authors believe. There is, however, a small point in the authors' treatment with which I must disagree. They correctly point out that disability glare has the beneficial effect of increasing adaptation but the deleterious effect of decreasing contrast. In the discussion of overhead streetlights, they compute relative visibility (delos) when the luminaire is out of sight and then when it is in sight. Relative visibility falls when the luminaire is in sight due to the deleterious—the contrast-reducing effect—of disability glare. Now, the authors say that the low value of relative visibility will persist due to the comparative speed of light adaptation. This is an error. Since dark adaptation is relatively slow compared to light adaptation, the beneficial (adaptational) effect of disability glare will persist when the luminaire is no longer in sight. However, the deleterious (contrast reducing) effect will disappear as soon as the luminaire is out of sight. Thus, once the luminaire is out of sight, relative visibility will rise over and above the high value originally associated with the case when the luminaire was out of sight.

D. E. Spencer and S. C. Peek:* We wish to thank the many discussers for their interest in our paper. It is evident that all of us are in agreement on the most important points. We agree that it is necessary to treat runway and turnpike lighting in a visually significant fashion. Both quantity and quality must be considered. We all agree that the delos method is on a sound foundation. We further agree that the method should be extended to include size of test object, duration of exposure, and transient conditions.

Next we will take up individual questions. Dr. Guth's comments indicate an understanding of the problem and of our approach to it. He questions the significance to the present discussion of the curves labeled *B* and *C*. They have no significance with respect to the paper except to indicate that qualitatively similar results can be expected with a variety of test objects. In Fig. 5, T_C represents the surround relative visibility (delos) based on minimum perceptible contrast. The notation is that of the papers of Reference 6. In the present paper the surround relative visibility (delos) is called T_S (defined in Eq. 6), the subscript *C* not being used because all of the development in this paper is based on minimum perceptible contrast. Dr. Guth shows misunderstanding of a detail in his comment on Eq. 7. The ***absolute value of relative visibility (delos) is entirely independent of the units used***, though the numerical coefficient in the denominator does depend upon the units. If H_B is expressed in blondels, then $(0.808 + H_A^{1/6})^2$ is also in blondels and the ratio (blondels/blondels) is a pure number. A detailed comparison of the Blackwell data with the older data shown in Fig. 3 has not yet been made. An adequate study of the Blackwell data is an important project for future research.

Dr. Guth interprets Figs. 8 and 9 as indicating that with "fog conditions . . . the loss with the high-mounted incandescent system is considerably less than that with the low-mounted fluorescent system." Quite the reverse is true. With the low-mounted fluorescent system, visual conditions in fog are always better than with the high-mounted incandescent system. With the low-mounted fluorescent system, good visual conditions are maintained even in fog. These good conditions are maintained at all times. With the high-mounted incandescent system, there are a few positions in which steady-state vision would be nearly as good as with the low-mounted system. These are labeled "Best visual conditions" in Fig. 9. The driver, however, must spend most of his time in the conditions described by the dotted curves of Fig. 7, which are far below those for low-mounted fluorescent lighting. In fact, both dotted curves for a dense fog and one of those for a moderate fog are so low that it was impossible to even plot them in Fig. 9. We have employed in our example the quantities of light likely to be used in actual installations of the two types. Experience leads us to conclude that quantity of light is relatively unimportant in producing this marked difference in performance. The key to the advantage of the low-mounted system is the fact that only a comparatively thin layer of fog is illuminated.

Dr. Guth also questions the visual effect of moving from lane 1 to lane 3 under the low-mounted fluorescent turnpike lighting. He seems worried about a gradual variation over 30 feet which is no greater than that continually encountered in much smaller distances with usual spotty and glaring overhead street lighting. Occasionally, the driver on this turnpike will encounter variations in adaptation. But these are moderate compared to the variations forced on him at every glance with IES-approved street lighting.

The effect of reflected glare from the hood is dependent on eye motions and on the exact shape of the hood. We have merely attempted to indicate the maximum effect. In Fig. 9, as the driver passes one glaring street light after another, his relative visibility (delos) varies over the region bounded by the upper solid curve and the lower dotted curve. This is a very wide variation. Exactly what point represents his relative visibility (delos) at any instant is a complicated function of the way he has moved his eyes, the speed and the path he has been traveling, the shape and color of the hood and dashboard of the automobile, and the exact position and design of the high-mounted incandescent luminaires.

We wish to repeat that the method is simple to use. Detailed calculations are less complex than the *BCD* calculations to which Dr. Guth has devoted so much effort. Simplifying short cuts can make most calculations relatively easy. And in actual practice, the method can be made exceedingly simple. All that we need is two photoelectric instruments to measure H_A and H_B. An illuminating engineer thus equipped can by-pass all of the alleged tedium and readily make a visually significant analysis of actual street lighting installations.

Mr. Wall's interest is greatly appreciated. We are happy to hear that the Roadway Lighting Committee is aware of adaptation. Our statement that "the engineering of outdoor lighting has generally neglected the state of adaptation of the eye" is, of course, based on published material. The Roadway Lighting Committee may have spent time and effort on the subject, but there is no evidence of this fact in their published reports.

Mr. Wall raises a question concerning the cost of continuous low-mounted fluorescent lighting. Our cost analysis indicates that for equal quantities of light the low-mounted system may be less expensive than conventional high-mounted lighting.

Mr. Wall also questions the possibility of manufacturing luminaires with the sharp cutoff assumed in this paper. Papers presented at the Toronto Conference gave data on actual luminaires which demonstrate sharp cutoff (Reference 2 in paper). Probably, the controlled fluorescent luminaires which Mr. Wall has obtained are not manufactured with sufficient accuracy. For sharp cutoff, extremely small tolerances must be maintained. Now let us consider Mr. Wall's numbered questions.

*Authors.

First: We regret that a quantitative analysis of visibility with a low-mounted fluorescent system in rain is not yet possible, due to the fact that goniophotometric measurements of pavements have not yet been completed. However, qualitative analysis and observation of actual installations lead us to expect comparatively good visual conditions even with wet pavements. The purely specular component is not visible to the driver and does not introduce the excessive glare encountered with overhead systems in rain. Enough light is reflected at non-specular angles to illuminate the pavement reasonably well. Objects in the road are well-lighted by the vertical component and are clearly visible.

Second: Unfortunately, a low-mounted system is not applicable where parked cars line the road or where bumper-to-bumper traffic is regularly anticipated. Thus, high-mounted lighting must also be studied.

Third: This type of lighting is particularly effective on exit ramps, interchanges, etc. where an area is to be illuminated and defined.

Fourth: Mr. Wall seems to have an erroneous picture of the appearance of a road illuminated by low-mounted fluorescent. The visual impression is that driving conditions are almost as good as in daylight. The large vertical component illuminates the sides of vehicles and pedestrians so that they are clearly and naturally visible. The freedom from glare experienced with this type of outdoor lighting makes night driving delightful.

Fifth: Maintenance at the Washington National Airport has been surprisingly good. Air currents produced as wind blows along the reflector contours produce a funneling action which clears the vicinity of the luminaires of all but a trace of snow. With proper design, the outer window could be cleaned periodically by a spray truck and inner surfaces should be undamaged by weather.

We are thankful to Charles Rex, both for providing an important part of the basic data used in the calculations and for his favorable comments.

It is unfortunate that Prof. Finch has not found time to understand the fundamental ideas in the paper. He finds mysterious ideas that can be clearly understood by the average lighting salesman or the average college student. In answer to the questions in the second paragraph of Prof. Finch's comments, we would like to refer him to Reference 6 in the paper. The data on which the relative visibility (delos) method, as presented here, are based are among the best substantiated of all visual data. A possible generalization to a wider variety of test situations should be made, using the Blackwell data and all other available data. However, this generalization would be expected to lead to essentially similar conclusions for a wide range of visual tasks.

Prof. Finch differs from many psychologists and many pilots in his analysis of the visual requirements for landing on a runway at night. The requirement is to accurately judge the location of the runway surface by visual clues. It is true that a rough estimate may be made if the surface is defined by dotted lines. It is also true that a much more accurate estimate is possible if textural gradients over the entire surface are visible (Reference 17 in paper). Thus, there is a definite advantage in seeing details on the surface of the runway.

One may compare the Finch button lights to lighting a room with a candle or two. This is a tremendous improvement over absolute darkness. But a lighting system which gives good general illumination is infinitely better, for most purposes, than candlelight. If the pilot sees the runway looking much as it does in the daytime, he can interpret the visual clues more readily and land with more confidence and accuracy than if he gropes his way toward a landing in the modern equivalent of candlelight. Even Prof. Finch's own account (Reference 16 in paper) indicates that the button-lights led to consistent misjudgment of the position of the runway surface.

Mr. Smith asks about the reflected glare from low-mounted fluorescent turnpike lighting. If he will carefully check the geometry of the situation, he will find that the reflected glare from low-mounted fluorescent lighting cannot be seen by the driver. On the other hand, the reflected glare from a high-mounted lighting system cannot be avoided by the driver.

He is also concerned about the possibility that a false surface may appear above the actual runway surface at the cutoff plane of the luminaire. In practice the illuminated fog layer does not have sufficient thickness to produce such an illusion.

We fully agree with Mr. Smith's suggestion that taxiways, as well as runways, should be lighted. However, as the visual task on the taxiway is not as crucial as that on the runway, a lighting system which provides guidance only may be tolerated here.

The history of floodlighting outlined by Mr. Smith is indeed dismal. However, it should be pointed out that the previous systems did not employ the sharp cutoff which is now attainable with macrofocal conic reflectors. Inadequate design has been the root of the previous difficulties. The installation at the Washington National Airport has already operated for nearly two years, while an improved system with even sharper control has recently been installed in Atlantic City.

Dr. Blackwell is certainly in basic agreement, since his own measurements can readily be adapted to expression in terms of the relative visibility (delos) concept. Again we repeat our hope of being able to incorporate the data recently made available to us by Dr. Blackwell into an extension of the relative visibility (delos) concept to short exposures. This extension and the development of simple instrumentation for measuring adaptation brightness (helios), are the prime topics for further research suggested by this paper.

We do not deny the importance of empirical tests of outdoor ilghting, although it should be pointed out that secondary scatter has been neglected because it appears not to be of importance in the range of variables employed here. Secondary scatter can well be included in the mathematical development if there is any indication that it is needed. With this addition, the mathematical problem becomes really interesting.

Dr. Blackwell's last paragraph is a discussion of our transient adaptation example. As he says, once the luminaire is out of sight, the state of adaptation H_A tends to remain at a higher level than was assumed in our calculations. However, as $H_A > H_B$, this means that while H_B remains as assumed in our example, T_B is actually less than assumed and thus the over-all relative visibility (delos) falls as we have stated. The glare from the street lights adapts the eyes to a high level. But as the street is comparatively dark, the driver is peering into the darkness while partially adapted to the luminaires. He could see more detail in the darkness if his eyes were permitted to remain at a low adaptation level.

A.I.A. File No. 31*f*

INSTALLATION ON FOURTH SOUTH ST., SALT LAKE CITY, UTAH

Lighting a City Street

LIGHTING OBJECTIVE: To provide a high level of roadway illumination for good nighttime visibility on a section of a city business street.

GENERAL INFORMATION: Fourth South Street is a state highway with heavy vehicular traffic. The pedestrian traffic is medium in the two-block section shown above (right). The length of these two blocks is 660 feet. The width is 132 feet from property line to property line and 103 feet from curb to curb. Street surfacing is black asphalt.

INSTALLATION: Lamp posts are sand blasted steel, coated with varnish-based aluminum paint. (They were converted from existing steel trolley poles.) Average spacing of the posts is 108 feet on both sides of the street for a total of 14 posts for the two-block section.

An average level of 4.01 footcandles is provided by one General Electric Co. Fluorescent "T" luminaire mounted 33 feet 6 inches above roadway surface on each post. The "T" luminaires consist of three units, as shown in photo at left. One unit containing four 72-inch TD-17 cool white 1500-ma fluorescent lamps is mounted on a two-foot bracket at right angles to the curb and tipped upward 15 degrees above the horizontal; the other two units, each containing two 72-inch TD-17 cool white 1500-ma lamps, are mounted horizontally on two-foot brackets parallel to curb, one on each side of the post.

Lighting designed by Don Peterson, Commercial Consultant, Business Development Dept., Utah Power & Light Co., Salt Lake City, Utah, in cooperation with E. Woodrow Walton, Street Lighting Supervisor for Salt Lake City.

Lighting data submitted by J. Homer Shaw, Commercial Director, Business Development Dept., Utah Power & Light Co., Salt Lake City, Utah, as an illustration of good lighting practice and to aid in the design of similar installations.

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Use of Computers in Design and Analysis of Luminaires

By BILL F. JONES

Calculation of luminaire performance has heretofore been limited primarily to those luminaires which control light by means of specular reflection or refraction. This paper outlines a method whereby, using an analogue representation of the luminaire, the performance of luminaires whose light-controlling surfaces are diffuse or semi-diffuse can be calculated, and useful information obtained on luminaires with mixed types of light-controlling media. Examples of computer calculations are included, and general ranges of accuracy are indicated.

THE AVAILABILITY of computers capable of solving sizeable matrix equations has created new methods of luminaire design and analysis. Previous papers[1,2,3] have shown how such computers are used in the solution of problems involving the distribution of flux in interiors, both from sources within the area and from those outside the area, entering through windows, skylights, and the like.

It is the purpose of this article to show how the same methods are used to predict the performance of a proposed luminaire design, while it is still in the drawing stage, and to indicate some of the advantages and limitations of this technique at the present stage of the art. For reasons of economy and speed, the luminous analogue computer[1,3,4] is more adaptable to this procedure than are digital computers, since the results of one analysis are used as the basis for revisions prior to another analysis. This iterative process, which usually leaves the majority of the programming unchanged, requires few changes in the set-up of an analogue computer, whereas in a digital computer the entire problem must be read in anew each time.

The theory and construction of this type of computer has been discussed previously.[1,3,4] It is suggested that reference 1 particularly be reviewed for an understanding of the relationships between the various functions which will be referred to in this paper.

A major use of this procedure to date has been the comparison of two similar proposed designs to indicate their differences in performance. This is a particularly useful facility in that it is much more sensitive than comparative tests, since with currently accepted photometric procedures two luminaires with identical efficiencies can appear as much as 4 per cent different upon test.

Analyzable Luminaire Types

The key to the entire matrix method of flux transfer analysis is the shape factor (shape modulus). This quantity is defined as the fraction of the total flux leaving one surface which is incident upon a second surface. Currently, the only types of surface for which shape factors are available are those which obey Lambert's law, so that their reflecting and transmitting characteristics are independent of the angle at which light strikes them. It is hoped that future applications—possibly of statistical or Monte Carlo methods—may result in shape factors for other types of surface.

Presently, however, this restriction has turned out to be less of a problem than was first surmised. Most of the commonly used surfaces within luminaires, such as painted or porcelain surfaces and diffusing glass or plastic, obey Lambert's law quite closely. Also, the higher the interreflections within a luminaire, the less the deviations from Lambert's law will matter, so that even for luminaires which have a principal surface departing radically from this law, a certain amount of useful information can be obtained.

Techniques have been available for years for analysis and design of luminaires whose surfaces reflect or refract in a specular manner. With the addition of a technique for handling primarily diffuse surfaces, there exists the possibility that a combination of techniques might be developed which will take care of combinations of such surfaces or for surfaces with intermediate characteristics. At present, however, the subject method is adaptable to the large majority of luminaires designed for commercial and industrial use.

One additional requirement is that the luminaire

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be of sufficiently low complexity to be programmed with sufficient accuracy on a computer of manageable size. So far the author has found no luminaires which cannot be accurately programmed on a computer with a twelve-surface capacity. Practically all luminaires possess at least one axis of symmetry, and each such axis, for reasons which will be detailed later, halves the number of surfaces required for programming. In certain instances, sections of a luminaire can be treated as a single surface with an effective reflectance,[2,5] thereby reducing further the number of surfaces to be programmed.

Predictable Quantities

For luminaires whose surfaces are essentially diffuse, the following characteristics can be predicted:

(1) *Efficiency.* This is one of the most useful predictions of the computer, and one which is reliable even for units whose surfaces differ widely from diffuse, such as lensed units. Calculations have been within 5 per cent of test results on all units tested to date, and within 2 per cent on all substantially diffuse units. The calculations are of such accuracy that it is debatable which, the test or the computation, is more in error.

Computation of efficiency is limited by the fact that the computer cannot evaluate the loss in lamp output due to heat. Radiated and conducted heat can be treated by this technique, but convected heat, which accounts for a large part of the transfer within the luminaire, cannot be so treated. Units without adequate ventilation, therefore, will compute higher than their service efficiency. If the effect of the type of enclosure on the lamp output has been evaluated by other means, it could be used to modify the calculated efficiency and give, again, an accurate answer. Incidentally, such a series of tests would be of considerable value in this day of surface mounted, recessed and enclosed units. The author has found drops in lamp output due to heat of the order of 20 to 30 per cent not uncommon, and feels that this accounts in large measure for the notable inefficiency of such units.

(2) *Upward and Downward Components.* This computation will be accurate regardless of the lamp temperature effects, and for any unit to which the method is at all applicable. It is rare that the tested and computed distributions will differ more than about two percentage points.

(3) *Luminaire Brightness.* The basic information delivered by the computer is the brightness of each surface within the luminaire. It is from these figures that the efficiencies and distributions are calculated. However, brightness is more sensitive to deviations from Lambert's law by the surface than is the lumen output of the surface. Therefore, while the computer will predict the average brightness of the surface, it will not indicate the brightness variations of sections which may reflect partly specularly. Similarly, its indication of brightness for matte surfaces will be accurate only insofar as their characteristics approach those of a perfect diffuser. In tests conducted to date, however, the computer has indicated within approximately 20 per cent of the measured brightness, which is quite useful.

TABLE I—Test vs. Computer Results for Three Luminaire Types.

Luminaire Type	Test Efficiency	Test Per Cent Up	Test Per Cent Down	Computer Efficiency	Computer Per Cent Up	Computer Per Cent Down
A. Semi-direct Industrial	85.5	21.5	78.5	86.5	21.9	78.1
B. Semi-indirect Commercial	78.0	85.0	15.0	78.0	84.6	15.4
C. Direct-indirect Commercial	79.8	51.8	48.2	80.5	53.0	47.0

(4) *Distribution Curves.* These are about as sensitive to deviations from cosine-law surfaces as the brightness readings. For luminaires whose surfaces are all diffusing, such as painted, porcelain, or diffusing glass, the distribution can be predicted rather accurately, varying from test by only 10 per cent to 15 per cent. For lensed units, the prediction is obviously worthless. However, lenses have rather characteristic distributions, and if the ratio of a lens' output to its maximum candlepower is known, the distribution can still be determined, since the computer will give the output of the lens.

Test vs. Computer Results

In order to check the reliability of the computer's figures, a number of units have been computed and also tested photometrically. The results of a few

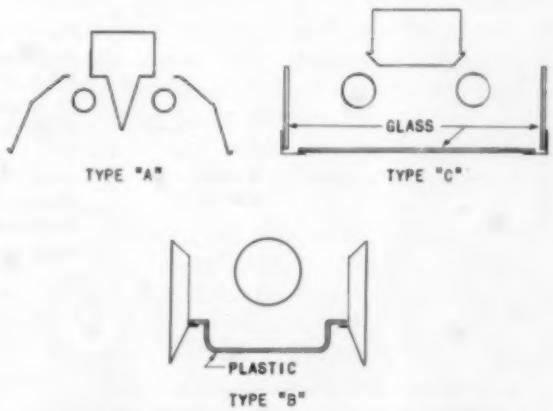

Figure 1. Types of luminaire compared in Table I.

of these tests are given as an indication of the type of performances that can be expected from this procedure, so far as a complete luminaire design is concerned.

Table I gives a comparison of test and computer results, comparing efficiency and upward and downward components. Cross sections of the luminaires are given in Fig. 1. For completeness of type coverage, luminaires which fell in the semi-direct, direct-indirect, and semi-indirect categories were chosen. None of these luminaires, incidentally, required the full capacity of the computer. Type C used the highest number, ten surfaces.

Fig. 2 gives a comparison of the brightness variation across the bottom of luminaire type C as measured and as computed. It will be noted that the computer brightnesses are, in general, slightly low. This is due to the fact that the diffusing glass used in the bottom of the luminaire is not perfectly diffuse, having a slightly higher candlepower in the perpendicular direction than it should. Also, due to imperfect diffusion, the lamps produce a slightly higher brightness directly beneath themselves.

Note, however, that the brightness variation across the luminaire is predicted almost exactly (within 3 per cent) by the computer, thereby giving an indication of the appearance to be expected from the panel, as well as the amount of contrast to be expected between the bottom and the sides of the luminaire.

Fig. 3 compares the tested and computed transverse distribution of the same luminaire. Note that the error is less than 15 per cent at most, and generally much less. For this particular luminaire, test and computation would be expected to agree fairly well, since all of its surfaces are quite close to diffuse. Curves for other units, of different configuration, have shown similar agreements.

Evaluation of the Effects of Design Changes

Useful as the computer is for predicting the performance of a new luminaire design, this is not its only use in this field. Many problems arise which can be solved by comparing the proposed change in design with its performance before the change. Some questions of this type which have been answered by the computer in recent months are:

What will be the difference in efficiency for two- and four-lamp luminaires of the same type?

What reflector contour will give the best performance for an industrial unit which is to be furnished in both porcelain and aluminum finishes?

What will be the difference in efficiency of a given reflector if we slant its sides or leave them straight?

How much will it cost in efficiency if we make a particular luminaire with a 35-degree cut-off instead of a 30-degree cut-off?

What will be the difference in performance of a luminaire designed for T17 grooved lamps with the grooves oriented up and down or sidewise?

For the same shielding angle, what is the difference in efficiency between 13- and 16-inch reflectors used with T17 lamps?

There are also problems which are hybrid be-

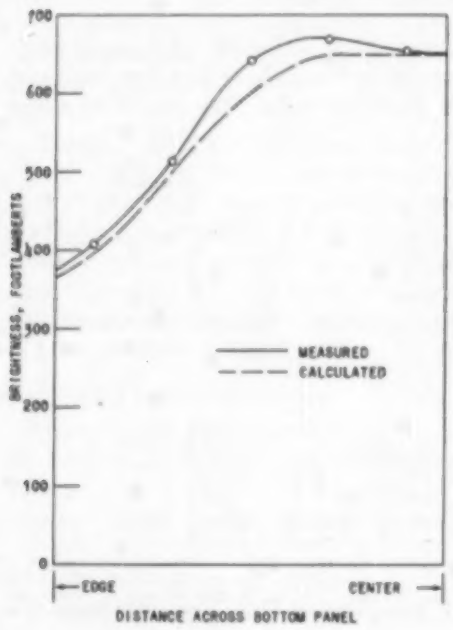

Figure 2. Calculated and measured brightnesses on bottom panel of luminaire C. Brightnesses adjusted to rated lamp brightness (L_{cn} = 2020 fL).

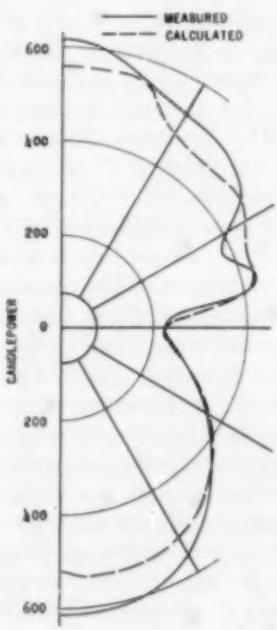

Figure 3. Calculated and measured transverse distribution curves for luminaire C.

tween luminaire design and lighting design which are extremely difficult to solve through test, such as large area luminaires and luminous ceilings, which yield readily to solution by computer. As an example, it recently became necessary for the author to determine what the effect on performance would be of filling in the spaces between indirect luminaires with louvers of a certain type, making thereby a "floating panel" luminaire of rather large extent. The same methods applied to luminaire design will give the answer to problems such as these.

Programming

It is impossible in this limited space to cover all the procedures that may be used for programming the computer to perform luminaire analysis functions. We can, however, indicate the primary methods used to divide a luminaire in the most convenient manner and to provide the most accurate results.

As has been stated, heretofore[2,3] the computer works by considering any area as composed of a group of surfaces, upon each of which the initial and final flux distributions are assumed uniform. To analyze any luminaire in an accurate manner, therefore, it must be so divided that this assumption is reasonably valid. For example, areas with different reflectances should not be lumped into the same surface, since there will be considerable difference in the final brightnesses of the two parts of the surface.

We can, therefore, write some general rules for dividing up a luminaire for programming on the computer. These rules will apply equally well to any other type of enclosure. For this process, the term "discretization" has been used,[4] and will be used here. Other comments on this topic can be found in references 3 and 4.

Generally, a surface should contain areas of only one reflectance, as noted above. Areas of the same reflectance should be of similar size, so that when the surface functions, calculated by the equation:

$$\text{surface function for area } m = \rho_m/(1-\rho_m)\,A_m \quad (1)$$

are translated into resistance they will not be of such widely differing resistance as to make programming on the computer difficult. ρ_m is the reflectance of surface m and A_m is its area.

The surface function section of the computer consists of three potentiometers per surface, having ranges of 100,000 ohms, 10,000 ohms, and 1000 ohms. Since it is very difficult to set a potentiometer accurately at less than one tenth its maximum value, this limits the range to resistances between 111,000 ohms and 100 ohms, or something over a thousand to one. This may seem like a large range, but a little checking will show that differences in area and reflectance of the order of 10:1 can result in differences of surface function setting of this magnitude. Of course, large areas of high reflectance can be used to balance small areas of low reflectance.

The transfer function section of the computer consists of two potentiometers per function, with ranges of 1,000,000 and 100,000 ohms, so the effective range of this section is from 1,100,000 to 10,000 ohms, or about 100:1. The transfer function is calculated from the equation:

$$\text{transfer function from surface } m \text{ to } n = 1/A_m F_{m\to n} \quad (2)$$

where $F_{m\to n}$ is the shape factor from surface m to surface n.

The product of A times F must therefore be kept within a range of 100:1 over the entire luminaire. Large areas and small shape factors might be balanced against small areas and large shape factors, but generally it is wise to try to keep both areas and shape factors within bounds since they are interdependent.

Within this framework of practicality in programming a unit on the computer, discretization should be done in the following manner:

(1) Use a large number of small areas where the flux is changing rapidly, and you would expect the brightness of the surface to change considerably in a small distance. Use larger areas and fewer of them where the flux is changing slowly.

(2) The natural geometry of the luminaire should be followed as much as possible, using boundaries between regions as the edges of surfaces.

(3) Break curved surfaces into a series of flat surfaces, following the general curvature of the surface. Use small areas where curvature is sharp and larger areas where it is gradual.

(4) Take advantage of symmetry. Any two surfaces of the same size which will have the same initial and final brightnesses can be lumped and called one surface. Since nearly all luminaires have at least one plane of symmetry, this effectively reduces the number of surfaces by one half, making it possible to discretize the luminaire into smaller lumps, making for greater accuracy.

(5) Use effective reflectances and transmittances where desirable. This point is covered in more detail below.

As an example, the discretization used for luminaire "C" is shown in Fig. 4. Note that a plane of symmetry exists down the center of the luminaire, with each surface on the left having its counterpart on the right. These are lumped together, giving twenty-surface accuracy using ten surfaces. Also note that all the flux from each of the surfaces is accounted for, *i.e.*, the boundary of the surfaces is

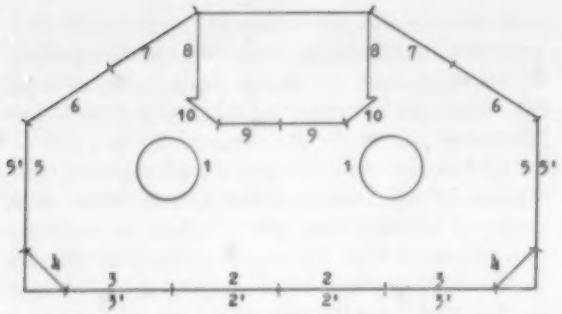

Figure 4. Discretization used on luminaire C.

a closed curve. Small jogs which intercept no significant flux can be ignored. Surfaces 6 and 7, though they are not actually present, must be included to close the curve. Note that two surfaces were used, while one would have served, since the effective reflectance and brightness are zero. This was done to keep the resistances on the computer within bounds, as discussed above.

Treatment of Cavities and Louvers

Effective reflectances and transmittances can be used to advantage when dealing with luminaries which have small cavities in them which would complicate the problem unnecessarily if they were programmed. The effective reflectance can be calculated by conventional methods[2,5] or obtained from charts.[2] Note in the discretization shown in Fig. 4 that the inside corner of the luminaire was replaced by a diagonal plane having the effective reflectance of the two corner surfaces.

The major use for effective reflectances and transmittances, however, is in the treatment of louvers. It would be highly impractical to program each surface of a louver as an element in the luminaire programming. By obtaining its effective reflectance and transmittance, a louver can be treated as a single surface. These effective values can be obtained by calculation or measurement.

Obviously, louvers neither reflect nor transmit in a cosine manner. For the measurement of efficiency this does not make much difference. Distribution curves can be obtained in a manner similar to that used for a lens. Brightness is the quantity that really suffers, but even this can be obtained by calculating the brightness of the louver blade after the problem has been through the computer. The illumination on the blade, E_a, can be determined by the relationship

$$E_a = L_1F_{a\to1} + L_2F_{a\to2} + L_3F_{a\to3} + \dots \quad (3)$$

where L_1, L_2, etc. are the final luminosities of the various luminaire surfaces, determined by computer, and the shape factors are from the louver blade to each of the luminaire surfaces. The illumination so determined is then multiplied by the louver blade reflectance to obtain the brightness. Normally this process should not be necessary, the brightness being estimated to sufficient accuracy from the known type of distribution of the louver and its output as determined from the computer.

Setting of Initial Conditions

For most luminaires, the initial conditions are quite simply set. The only surfaces initially emitting are the lamps. With fluorescent lamps, the initial brightnesses are determined by dividing the output by the area, and only this one set of inputs needs to be fed to the machine. With incandescent lamps, the initial distribution of the lamp flux on the inside of the luminaire can be determined from the distribution curve of the lamp and drawings of the luminaire. This may be desirable, since it is often difficult to determine the lamp's initial brightness, and it is normally not very uniform anyway. If this method is used, the lamp becomes an obstruction in the luminaire, with no initial brightness. Having determined the initial brightness of each luminaire surface, these initial brightnesses are fed into the computer as initial luminance functions. In this case there will probably be nearly as many initial sets of conditions as there are surfaces, since only the openings through which light passes unobstructed (and whose effective reflectance is therefore zero) will not have initial brightnesses.

In the most common case, though, where the lamp can be used as the only input, the initial luminance function,

$$\text{initial luminance function} = L_{om}/(1-\rho_m) \quad (4)$$

is set and the computer then reads out the final luminances of all the surfaces of the luminaire. In the above equation, L_{om} refers to the initial brightness of the surface, a lamp in this case.

Post-Computer Calculations

With this accomplished, the only remaining problem is the determination of how much light comes out of the luminaire from these surfaces. There may be three cases: light directly from the lamp, light reflected from luminaire parts, and light transmitted through luminaire parts.

Light directly from the lamp and that from reflectors are handled in the same manner. The flux through each opening of the luminaire is determined by the equation:

$$\text{Flux through opening } a = E_aA_a$$
$$= A_a(L_1F_{a\to1} + L_2F_{a\to2} + L_3F_{a\to3} + \dots \quad (5)$$

Light transmitted through glass, plastic, louvers,

TABLE II—Programming for Luminaire C.

Surface	Area (linear)	$\rho_m/(1-\rho_m)A_m$	Resistance*	Final Luminosity	Actual Area (ft²)
1	9.42	.318	9.54	1955	3.14
2	5.06	.073	2.19	240	1.69
3	5.06	.073	2.19	172	1.69
4	2.00	.861	25.83	402	.67
5	6.00	.062	1.85	172	2.00
6	4.88	0	0	0	1.64
7	4.75	0	0	0	1.58
8	3.12	1.28	38.4	36	1.04
9	2.81	1.42	42.6	529	.90
10	2.38	1.68	50.4	793	.79

Surfaces m-n	Transfer Function $1/A_mF_{m\to n}$	Resistance*	Surfaces m-n	Transfer Function $1/A_mF_{m\to n}$	Resistance*
1-2	.625	18.75	3-8	-	-
1-3	.743	22.29	3-9	1.81	54.3
1-4	1.77	51.1	3-10	-	-
1-5	.708	21.24	4-5	2.63	78.9
1-6	.753	22.59	4-6	2.27	68.1
1-7	1.13	33.9	4-7	5.21	156.3
1-8	-	-	4-8	12.5	375
1-9	1.40	42.0	4-9	33.3	1000.
1-10	.885	26.55	4-10	27.8	834.
2-3	-	-	5-6	1.68	50.4
2-4	15.2	456.	5-7	4.17	125.1
2-5	1.27	38.1	5-8	2.11	63.3
2-6	2.41	72.3	5-9	-	-
2-7	4.82	144.6	5-10	2.11	63.3
2-8	-	-	6-7	-	-
2-9	.641	19.23	6-8	4.10	123.0
2-10	2.25	67.5	6-9	-	-
3-4	5.34	160.2	6-10	3.15	94.5
3-5	.816	24.48	7-8	.52	15.6
3-6	.784	23.52	7-9 to		
3-7	2.44	73.2	9-10	-	-

L_m = Lumens/Area = 2650/1.571 = 1689 fL (based on uniform 48-inch lamp)
Luminosity function = $L_m/(1-\rho_l)$ = 1689/(1—.75) = 6750
τ_{glass} = .63; ρ_{glass} = .27; $\rho_{reflector}$ = .80; ρ_{lamp} = .75; ρ_t = .62

LUMINOSITY OF OUTSIDE SURFACES:

$L_2' = L_2\tau_2/\rho_2 = 560$
$L_3' = L_3\tau_3/\rho_3 = 401$
$L_5' = L_5\tau_5/\rho_5 = 401$

OUTPUTS:

$\phi_2' = L_2'A_2 =$ 946
$\phi_3' = L_3'A_3 =$ 678
$\phi_5' = L_5'A_5 =$ 802
$\phi_0 = A_0E_0 = A_0\Sigma L_m F_{0\to m} =$ 1160
$\phi_T = A_TE_T = A_T\Sigma L_m F_{T\to m} =$ 680
$\phi_{total} =$ 4266

Fixture output = 4266 lumens
Lamp output = 5300 lumens
Efficiency = .805
*In kilohms, const. = 30,000 ohms

etc., is determined by first finding the brightness (luminosity) of the outside surface of the element by the equation:

$$L_m' = L_m\tau_m/\rho_m \qquad (6)$$

where L_m' is the luminosity of the outside surface, τ_m is the transmittance of the material and ρ_m is its reflectance. The output is then equal to this luminosity times the area of the surface.

To aid in following through the steps of such a procedure, the complete programming and computer results of the calculation on luminaire C are shown in Table II. Efficiency was determined by computing the output of each external surface, and summing. Distribution was determined by multiplying the projected area of each surface at each angle by its brightness and summing. Brightness variation was found by plotting the illumination across the bottom panel by equation 3, and using equation 6 to get the outside surface brightness therefrom.

Shape Factors

About the only major problem remaining is how to get the shape factors required without a great expenditure of time and labor. In the evaluation of fluorescent luminaires we are aided by the fact that once a surface is about four times as long as it is wide, its shape factor to adjacent surfaces does not vary much from that for an infinitely long surface. This reduces nearly all fluorescent problems to a two-dimensional situation, requiring only a cross-section of the luminaire for solution. To be assured that such is the case, all that is needed is to remember that the efficiencies, distributions, and brightnesses of two-, four-, and eight-foot fluorescent luminaires of the same type are almost identical.

Recognizing this fact makes it possible for us to use shape factors for two-dimensional cases, which are much simpler of evaluation. Taking one further step simplifies the problem even more. The shape factor from a differential area to a finite area in a two-dimensional case can be determined by use of an ingenious scale, or "protractor" developed by Centeno and Zagustin.[6] This scale is reproduced in Fig. 5. To use it, place the center at a point on the surface from which the shape factor is wanted, parallel to that surface. The edges of the other area will intercept an angle on the protractor. Subtracting the smaller protractor reading from the larger gives the shape factor.

This chart is accurate only for point-to-surface shape factors. To obtain the surface-to-surface shape factor, it should be remembered that this is defined as the average shape factor of all points on one surface to the other surface. By taking the shape factor with this chart at a few points on the surface and averaging, the surface-to-surface factor is obtained. Normally not many points are needed. For the problems whose solutions are given in this paper, four points or less were used, and normally only one or two.

Charts of this type are useful for other types of area than planes (to which this chart applies). Shape factors for lamps of asymmetrical distribution in particular are facilitated by such charts. A chart for a T17 grooved lamp is shown in Fig. 6. Even for symmetrical fluorescent lamps these charts are useful, though the shape factor from such a lamp is easily found, being equal to the fraction of

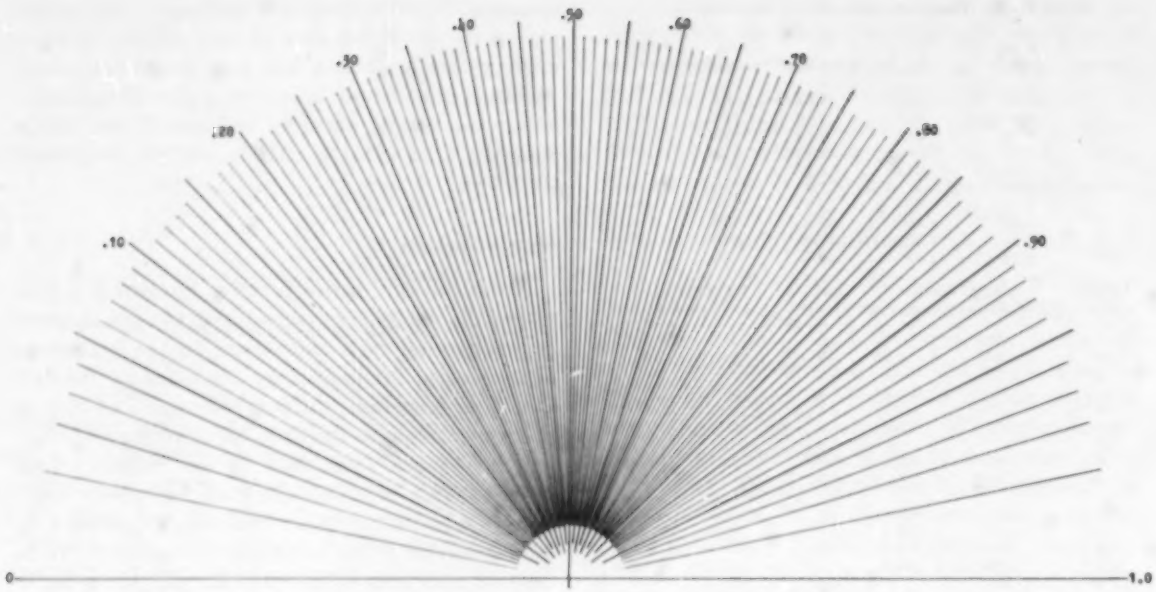

Figure 5. Centeno-Zagustin shape factor scale for two-dimensional differential-area-to-finite-area case.

a complete circle subtended by the surface at the lamp.

For cases where this chart cannot be used, shape factors are available in the form of equations, charts, and tables, one of the best of which is cited as reference 7.

Conclusions

The general methods by which a digital or analogue computer can be used as an aid in the process of luminaire design and analysis have been discussed, and the range of accuracy and application at this state of the art has been evaluated. The present fields of applicability have been designated as follows:

(1) Luminaire performance can be evaluated from a set of drawings rather than requiring a model for test.

(2) Effects of design changes can be evaluated.

(3) Performance of systems too large or otherwise unsuitable for test can be calculated.

(4) Effects of individual variables can readily be separated for analysis.

(5) The basic lighting performance of a system can be separated from the subsidiary effects, such as ventilation, heat, orientation, etc.

From an evaluation standpoint, it is felt that in these days of increasing size of luminaires, where luminous ceilings are becoming more prevalent, and basic elements are reaching astounding sizes, item (3) above may well be the most important in the near future. For reasonable accuracy of lighting calculations, we will need to know the effective reflectance of these large area luminaires, which is difficult to test, but simple by computer. The heat build-up in enclosed luminaires is such that the lighting performance is often badly degraded. Knowing the magnitude of such loss may be of assistance in providing service to the customer.

It is felt that proper use of computing machinery of this type will result in a higher level of sophistication in luminaire and lighting system design in

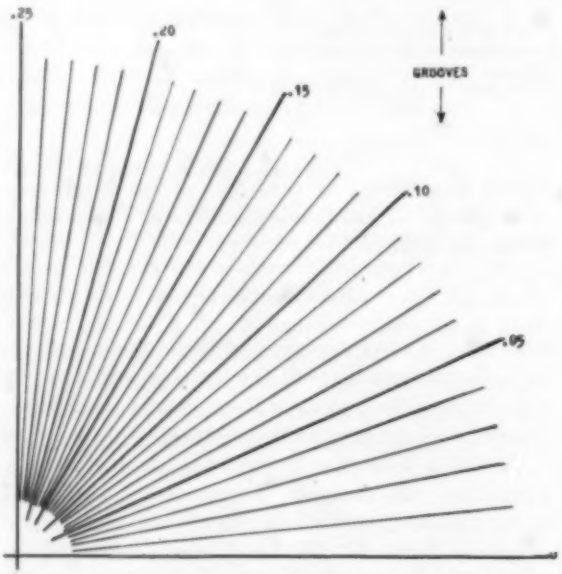

Figure 6. Shape factor scale for T17 grooved lamp.

the future. The capabilities of the approach have only been scratched.

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DISCUSSION

PHILIP F. O'BRIEN:* The author has demonstrated in a convincing manner the applicability of the luminous analog computer to the important problem of luminaire design. He has shown that the properties of a luminaire which contains diffusing elements can be accurately predicted when the luminaire exists only in the form of a paper and pencil representation.

The evaluation of the effects of design changes on the over-all performance of the luminaire is discussed by the author. Solutions to design problems of this kind are obtained by using the luminous analog computer as a true simulator; that is, the network representation or model of the luminaire is set on the computer and then small changes in radiant properties, geometry and lamp location can be effected and the results observed by merely adjusting the analogous electrical resistances and potentials. In this manner, the final luminaire can be synthesized to some optimum condition by a repetitive or iterative process using the computer as a simulator. With the utilization of this technique, the computer is a mathematical model of the luminaire and is not used merely to solve equations.

The use of physical models is well-understood in lighting design; the use of mathematical models or simulators in the design of lighting, however, is a new and promising technique.

E. H. SALTER:** Such an arrangement as Mr. Jones has given us in his paper should make it possible for a luminaire designer to predict luminaire performance characteristics with a relatively high degree of assurance. In fact, Mr. Jones suggests that it is somewhat debatable whether the computed result or a test result of the luminaire is the more reliable.

This touches on a point to which I have given a considerable amount of attention over the last several years; namely, the interpretation of test data from luminaire tests. Ordinarily, due to cost limitations, only one specimen of a given luminaire is subjected to a photometric test and the results of that test frequently are used to represent to the nth-degree the performance characteristics of that product.

There are a number of reasons why it may not be justifiable to use such test results as an absolute representation of the performance of luminaires of the type and make covered by a single test report. In the first place, there are limitations to the accuracy to which any measurement may be made. Photometry is no exception and measurements of a given lamp or unit normally are considered reasonably precise if they can be repeated to within one or two per cent.

A second, and probably more important factor, however, is the reproducibility of the lighting unit itself. Very few luminaires are precision made. That is, parts may not be exact duplicates in size and shape, the finish of reflecting parts may vary from one to another, lamps normally are not exact duplicates either in dimensions or performance, and where transmitting parts are used, such as glass or plastic, photometric properties may vary widely. All of these elements combine to give possible wide variations in performance characteristics from one luminaire specimen to another.

Since experience has shown that these presently uncontrolled variables enter into performance test results to, in some instances, give wide differences between the performance characteristics of ostensibly duplicate luminaire specimens, it must be pointed out that computed performance might be expected to vary from actual performance due to these same variables. Computations of luminaire performance can then be expected to represent actual luminaire performance only to the extent to which luminaire parameters on which the computations are based truly represent the assembled luminaire as produced. Computed results may therefore represent the performance of the luminaire that the manufacturer sets out to produce rather than the performance of luminaires as they come off the production line.

All of this means that differences in luminaire efficiencies, obtained either by a single test or by computation, amounting to a few per cent up or down, may have little or no significance in determining the performance of the luminaires that may be furnished for a given installation. Since coefficients of utilization are derived from such performance data, they too are subject to the same criticism, *i.e.*, small differences, in second or third significant figures, may be relatively meaningless in evaluating the performance of luminaires furnished for a given installation.

I know that the choice of a luminaire for a given installation frequently has been made on the basis of such small differences in efficiency or coefficients of utilization. When it is realized that such differences may not have any real significance, it is seen that such a choice may not always be a wise one. Lighting engineers should be made cognizant of these facts.

The tool described by Mr. Jones should prove useful if these limitations are known and understood, but any claim of greater accuracy than actual luminaire testing will have to be weighed against the ability of the luminaire manufacturer to produce the luminaire that he designs.

BILL F. JONES:* I should like to thank Messrs. O'Brien and Salter for their comments on this technique of fixture analysis. It was through my association with Professor O'Brien that I first became acquainted with the adaptation of basic theory that made possible the computer techniques which have been applied in this paper to the problem of calculating fixture performance. Without the definitive work

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done by Professor O'Brien, this approach would not have been possible.

Mr. Salter has stated some facts with which I heartily agree. It is amazing how much ignorance of the basic facts of photometric accuracy and manufacturing tolerance exists in our industry. We manufacturers must undoubtedly assume partial responsibility for this ignorance, through our competitive sales efforts. One manufacturer even emphasizes that his tables of coefficients are calculated to *five-place* accuracy by computer (he only prints two figures in his catalog, luckily!).

In the interests of trying to separate photometric tolerances from manufacturing variations, I checked data from numerous tests on a fixture which is rather easy to manufacture to close tolerances, an RLM industrial unit. The range of the series of tests showed from 83.0 to 88.5 per cent efficiency for samples of the fixture which all had the same measured reflectance, shielding angle, candlepower ratio, etc. This is a variation of plus or minus 3.2 per cent, and shows just how futile it is to base acceptance or rejection of a fixture on a few per cent difference in efficiency or coefficient! There are much more important factors than this to consider.

This problem deserves much more attention than has been devoted to it in the past, and certainly much more discussion than can be printed in these pages. It would seem that a paper should be prepared covering the limits of accuracy of our currently accepted photometric testing, perhaps for the next IES Conference. The person probably best qualified to write such a paper is Mr. Salter, and I should like to recommend strongly that he be invited by the Society to do so.

As far as test and computer comparisons are concerned, the fixtures quoted herein were computed using the actual values of reflectance, transmittance, etc., used in the particular fixtures tested. Manufacturing tolerances, therefore, do not enter greatly into the comparisons. We have since, however, constructed fixtures which were computed before models were built. One such fixture was a design which could not be tested, since it involved a reflector die which could not be changed and therefore had to be right the first time. Without the computer, we would have had to estimate the performance and hope we were right. With the computer, we designed the die to calculated performance. Our faith in our calculations was justified; the tested performance was fully in line with the calculations.

Utility Office Meets Recommended Level

The first commercial application of extra-high-output fluorescent lamps in the San Diego area has shown satisfactory results in the East San Diego branch office of the San Diego Gas & Electric Co. This experimental installation utilized 1500-ma, 15,000-lumen lamps set in nine two-lamp, 45-degree luminaires, each equipped with a 12-inch stem, at a mounting height of 11 feet. Maintained illumination level is 160 footcandles. Quality of the lighting provided by the louvered fluorescent luminaires is further enhanced by the light-colored surfaces of the walls, desk tops and floor.

Data and photo courtesy of Carlton M. Thompson, Commercial Lighting Dept., San Diego Gas & Electric Co., San Diego, Calif.

INSTALLATION AT JOHN DREW MOTORS, DODGE-PLYMOUTH AGENCY, 2600 ARDEN WAY, SACRAMENTO, CALIF.

Lighting a Used Car Lot

LIGHTING OBJECTIVE: To create an attractive, floodlighted location for merchandising used automobiles.

GENERAL INFORMATION: The lot is located on a corner site of which the street frontage measures 210 feet on Arden Way and 175 feet on Fulton Avenue.

INSTALLATION: Five 30-foot poles are located along the property line on Arden Way and five 25-foot poles are located along the property line on Fulton Avenue. These poles are spaced approximately on 40-foot centers. In the rear there are two additional 25-foot poles.

There are 14 Stonco Electric Products Co. catalog No. 6401-WF weathertight floodlights, each equipped with one 500-watt PAR-64 medium flood incandescent lamp, mounted on each of the ten perimeter poles for floodlighting the cars. There are seven of the same floodlights mounted on each of the two rear poles for illuminating the rear of the lot and to provide protective lighting. Catalog No. 15-A wiring troughs are used for pole mounting the luminaires.

After approximately one month's operation the illumination on the first outer row of cars was 65 footcandles at hood height. Thirty feet back from the sidewalk the average level was 20 footcandles. At the corner of Arden Way and Fulton Avenue, where the feature car is located, the level is 125 footcandles.

Lighting designed by Elton Harris, Commercial Lighting Representative, Sacramento Municipal Utility District, Sacramento, Calif. Electrical Contractor was Merrill Electric, Carmichael, Calif.

Lighting data submitted by Elton Harris as an illustration of good lighting practice and to aid in the design of similar installations.

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Improvements in Fluorescent Lamp Efficiency From Particle Size Control of Phosphors

By K. H. BUTLER
H. H. HOMER

THE NECESSITY for milling phosphors to remove the large particles has long been a troublesome problem since, in a majority of cases, this milling has reduced the intrinsic brightness of phosphors. This has been particularly detrimental in fluorescent lamp manufacturing.

Many qualitative explanations have been presented for this loss of brightness. One early idea was that strains are created in the crystal lattice during the manufacturing of the phosphor and were the source of fluorescence. The mechanical work done on the phosphor during the milling removed some of these strains and reduced the amount of fluorescence.

It is known that a large number of very small phosphor particles are produced during the milling with the number of such particles increasing with milling time. We found empirically a definite relationship between the amount of fines present and lowering of lumen output. Previously, we considered two alternate explanations. One was very poor fluorescence of small fragments of the crystal due to size alone, while another was loss of activator from the phosphor particles during heat treatment in processing of lamps. This loss of activator was determined by the surface area, with the small particles having very high area per unit weight. Both of these theories have shown obvious deficiencies.

The present work accepts the explanation of the role of the small particle in causing loss of lumen output and shows that the major factor influencing the loss is not absorption of visible light, but is back scattering and subsequent loss, by absorption in the arc, of the 254 mμ energy. The amount of this back scattering is shown to be a function of the particle size distribution of the phosphor and increases with an increase in the amount of fine particles present in the phosphor layer.

Bodo and Hangos[1] have also shown that phosphors in powder form do not completely absorb the ultraviolet. They have given some useful calculations as well as data for reflection of ultraviolet by phosphors of varying particle size, but did not consider the performance in lamps. In their calculations Bodo and Hangos assumed no absorption of visible light.

Ouweltjes[2] has given a qualitative discussion of the effect of particle size on lamp performance, but stresses that complete absorption of ultraviolet is important and concludes that very fine phosphors are to be preferred if the absorption coefficient is sufficiently high.

Theory of Coating Behavior

The primary function of the phosphor coating in a fluorescent lamp is absorption of ultraviolet radiation and conversion of this absorbed energy into visible light. Phosphors are generally prepared by heating together a number of chemicals at temperatures below fusion. After further processing, the resulting product is a fine powder which is applied as a thin layer on inner glass surface of lamp.

It is readily possible to calculate that a 40-watt lamp delivers 22 watts of 254 mμ radiation to the phosphor and that this will give a light output, including the visible mercury lines, of 3800 lumens or 95 lpw, when a 3500K white halophosphate phosphor is used. Present lamps therefore show only 75 per cent of theoretical efficiency and our knowledge of the reasons for this poor performance has been limited.

Since milling had a major effect on phosphor performance, with the production of fines being recognized as a vital factor in the reduction of lumen output, it was logical to investigate, theoretically, the relationship between particle size and lamp performance.

Fig. 1 is a schematic diagram showing the behavior of visible and ultraviolet radiation in a lamp. In the left part of the diagram, the 254 mμ ultraviolet generated in the arc stream hits the phosphor at point A. A large fraction, A_1^{uv}, is absorbed by the phosphor causing fluorescence. A small fraction, not shown, escapes through voids in the phosphor layer and is absorbed by the glass, while the fraction, R_1^{uv}, is scattered or reflected back toward the arc stream. At point B in the arc stream this is absorbed by the mercury atoms and the fraction,

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHORS: Sylvania Lighting Products, Salem, Mass. Accepted by the Papers Committee as a Transaction of the IES.

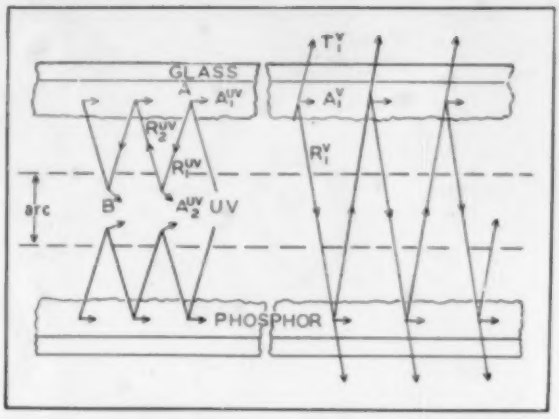

Figure 1. Schematic diagram showing behavior of ultraviolet and visible radiation in a fluorescent lamp.

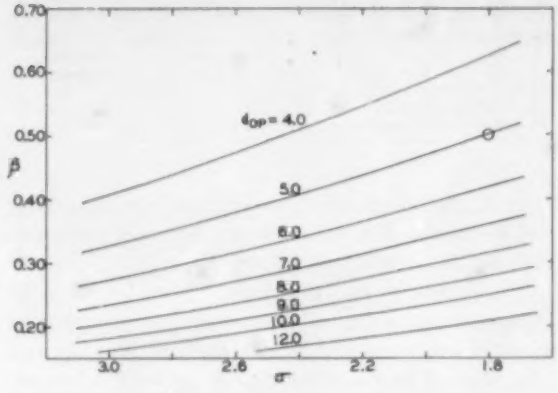

Figure 2. Variation of the scattering constant β with particle size parameters d_{op} and σ.

R_2^{uv}, is re-emitted as ultraviolet energy. R_2^{uv} may be considered as the effective reflectance of the arc.

In the right half of the diagram, the visible fluorescent light is generated at point A on the inner surface of the phosphor. A fraction, T_1^v, is transmitted through the layer, after loss of a small fraction, A_1^v, by absorption. Another large fraction, R_1^v, is scattered or reflected into the interior of the lamp, passes through the arc stream without being affected, and hits the phosphor at point C on the other side of the lamp when it splits into the same three fractions. Thus, the visible light goes through numerous internal reflections until all of it is either transmitted outside the lamp, or is absorbed in the coating. Both processes shown occur simultaneously.

The interesting theoretical problem is how to obtain numerical values for absorption, reflection, and transmission which will allow prediction of lamp performance. A new approach[3] to the problem was attempted by considering that the phosphor layer in a fluorescent lamp behaves optically as a diffusing layer and that the classical equations[4,5] for the scattering of light can be used. The absorption, transmission and reflection of the phosphor layer can be calculated by these equations, which apply both to the ultraviolet radiation and to the visible light generated by fluorescence.

For either ultraviolet or visible radiation, incident on a coated portion of the bulb, the fraction absorbed is given by

$$A_1=\frac{\mu\sinh Kt+K(\cosh Kt-1)}{(\mu+\beta)\sinh Kt+K(\cosh Kt)} \qquad (1)$$

In this equation, μ is the absorption constant per unit thickness of the phosphor layer; it is strongly dependent on wavelength but independent of the particle size of the phosphor. β is the scattering constant; it is independent of wavelength and is proportional to the total cross-sectional area of the particles in a unit volume of the layer. Hence, the smaller the particle, the greater the reflection. K is related to μ and β by the equation $K^2=\mu(\mu+2\beta)$; and t is the thickness of the layer, proportional to the coating weight in grams of phosphor per square inch of surface. Sinh and cosh are the hyperbolic functions found in the usual mathematical tables.

Using the same symbols, the fraction of radiation reflected by the phosphor layer is given by

$$R_1=\frac{\beta\sinh Kt}{(\mu+\beta)\sinh Kt+K\cosh Kt} \qquad (2)$$

If the effective reflectance of the arc stream for ultraviolet is R_2 the total energy absorption by the phosphor layer is given by

$$A_m^{uv}=\frac{A_1^{uv}}{1-R_1^{uv}R_2^{uv}} \qquad (3)$$

Since R_1^{uv} is usually less than 0.2 for ultraviolet in lamps, only a small error will be made by assuming R_2^{uv} is equal to zero and Eq. (1) can then be used to determine the ultraviolet absorption.*

If the thickness of the phosphor layer is increased indefinitely, Eq. (2) reduces to

$$\frac{1}{R\infty}=\frac{\mu}{\beta}+1+\sqrt{(\frac{\mu}{\beta}+1)^2-1} \qquad (4)$$

Thus a measurement of the reflectivity of the bulk phosphor will allow the ratio μ/β to be calculated for a given phosphor at any wavelength at which $R\infty$ is measured. The scattering coefficient β is determined by the particle size distribution of the phosphor and can be calculated by the equation

$$\log\beta=\log k-\log d_{op}-1.1513(\log\sigma)^2 \qquad (5)$$

*This approximation can be made better by giving μ a slightly higher value than that found experimentally. In any case, R_2^{uv} is independent of the phosphor.

TABLE I—Typical Absorption and Scattering Constants.

	Ultraviolet 254 mμ	Visible 550 mμ
β	0.15—0.40	0.15—0.40
μ	1.00	0.003

Here d_{op} is the optical diameter[5] and σ is the standard deviation; k is an arbitrary constant chosen so that $\beta = 0.5$ when $\sigma = 1.8$ and $d_{op} = 5.0$.

The constants in Table I have been found to be reasonable for a typical halophosphate phosphor in a coated lamp and can be used in Eqs. (1), (2) and (6), with β being calculated accurately by equation (5). Another basic equation gives the transmission through the phosphor layer

$$T_1 = \frac{K}{(\mu+\beta)\sinh Kt + K\cosh Kt} \qquad (6)$$

If the internal multiple reflections are to be considered, as is the case with visible light, then the transmission becomes

$$T_m^v = \frac{T_1}{1-R_1^v} = \frac{K}{\mu\sinh Kt + K\cosh Kt} \qquad (7)$$

Fig. 2 shows the effect on the scattering constant β caused by changes in d_{op} and σ. It is obvious that small β values are obtained only when the average size is large; and since β is inversely proportional to the diameter small particles present in the phosphor will raise β very quickly. Table II shows values for reflection, transmission, and absorption of the phosphor layer, which have been derived from detailed graphs[3] using the usual coating thickness in a typical lamp.

With increasing thickness of phosphor, A_1^{uv} for incident ultraviolet first rises very rapidly and then levels off to a nearly constant value determined by μ/β, while T_m^v for the visible fluorescent light starts at 1.00 and falls off very gradually. It is obvious, therefore, that the lamp efficiency will be determined by the product of two factors, A_1^{uv} for the ultraviolet and T_m^v for the visible light. This product

$$E = T_m^v \times A_1^{uv} \qquad (8)$$

must therefore have a maximum value at some value of T which is determined by the value of β,

TABLE II—Properties of Lamp Coatings With Thickness t = 5.0.

	Ultraviolet	Visible
β	0.5	0.5
μ	1.0	0.003
A_1	0.804	0.015
R_1	0.195	0.546
T_1	0.001	0.439
T_∞	....	0.967

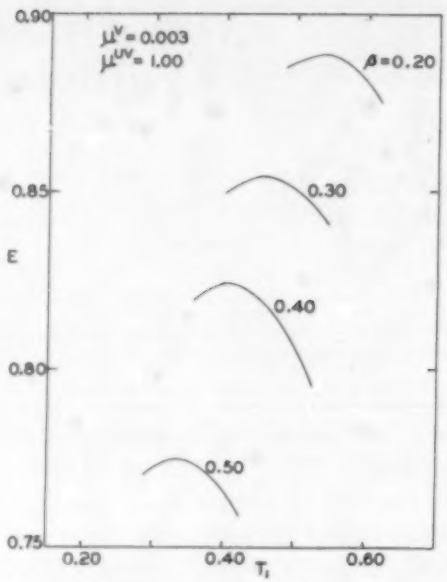

Figure 3. Typical variations in theoretical lamp efficiency with changing phosphor transmissions for various scattering constants ($\mu^v = 0.003$, $\mu^{uv} = 1.00$).

provided μ^v and μ^{uv} remain constant for the difference phosphors. That is, the lamp efficiency is determined by the particle size distribution of the phosphor.

Fig. 3 shows typical curves of efficiency as a function of T_1^v for various values of β. In this figure, T_1^v is chosen as the variable rather than thickness, because in practice the coating is generally controlled by a measurement of transmission or reflection of visible light. Fig. 4 shows how the maximum efficiency varies as the β value of the phosphor changes when T_1^v is at the optimum value

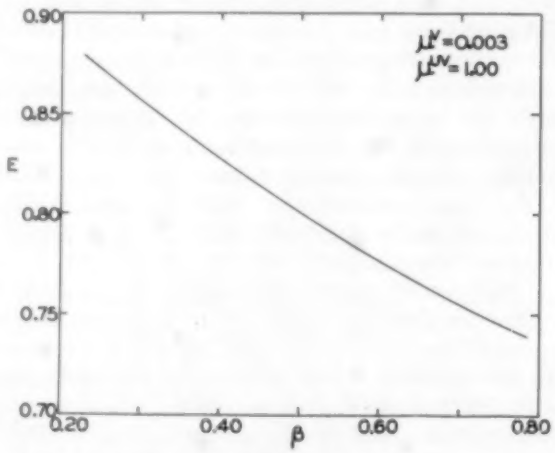

Figure 4. Theoretical variation in maximum lamp efficiency at optimum T^v_1 with changing scattering constant ($\mu^v = 0.003$, $\mu^{uv} = 1.00$).

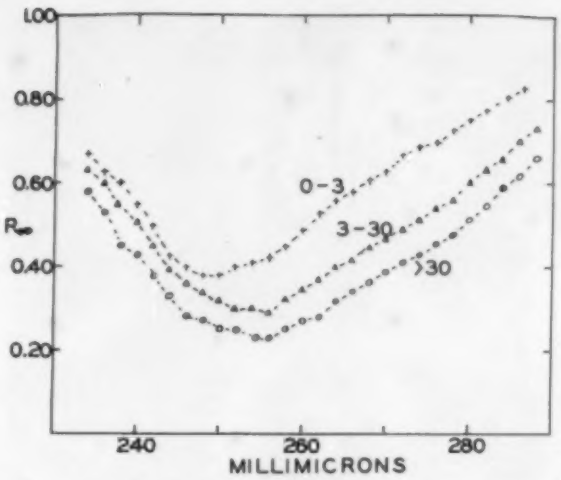

Figure 5. Variation of reflectivity vs wavelength for halophosphate phosphors having three different particle size ranges.

for each β. It is readily apparent from these two figures that the lamp efficiency varies drastically with changes in β and that the value of T_1^v also changes with β. Use of incorrect values of T_1^v can cause a marked efficiency loss.

Experimental Data on Bulk Phosphor

The theoretical discussion has indicated that the value of μ for ultraviolet is a major factor determining phosphor behavior. This can be estimated by measuring the reflectivity of phosphors of known particle size. The value of μ for visible light can be determined in the same way.[7] Measurements of the reflectivity of three samples with different particle size ranges, obtained from the same lot of phosphor by classification, are shown in Fig. 5. These show the change in reflectivity predicted by theory. Fig. 6 shows the variation of μ/β for one of these samples. From these curves, combined

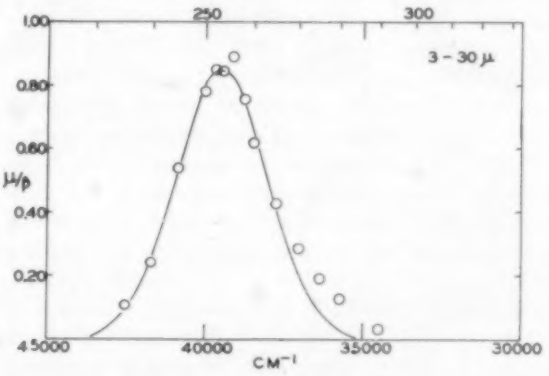

Figure 6. Typical variation with changes in wavelength of the ratio of absorption to scattering constants.

TABLE III—Optical Constants of Classified Phosphors.

Sample	Max. μ/β	β	Max. μ	% Sb
0—3μ	0.50	0.60	0.30	1.15
3—30μ	0.85	0.29	0.25	1.23
>30μ	1.30	0.21	0.27	1.17

with particle size data, the constants of Table III were calculated.

It is of interest to note that even though μ/β varies by a factor of 2.6, the calculated absorption constant varies only 10 per cent away from the average. This constant value of absorption constant would be expected from the lack of variation in the activator concentration (per cent Sb) and indicates that even the fine particles would have good fluorescence. The values of μ are somewhat below those used for the theoretical curves of Figs. 3 and 4. Thus, these particular theoretical curves are compensated for the partial reflectance of ultraviolet by the arc.

Experimental Data on Lamps

The laboratory measurements on bulk phosphors have confirmed the basic concept of the effect of particle size on ultraviolet reflection. The theoretical discussion shows also that the surface area per unit volume of phosphor, *i.e.*, the specific surface, determines the scattering constant and hence the light output. Since the specific surface is inversely proportional to particle diameter, a small proportion of super-fine particles should have a marked effect on lamp properties. (In this paper, we will define "super-fines" as those particles smaller than three microns in diameter.)

Microscopic examination of phosphors, when ready for preparation of coating suspension, shows particle sizes may range from 200μ to less than 1μ. Milling has always been required to reduce the coarse particles to the size range required for appearance and adhesion to the lamp. Fig. 7 shows an electron microphotograph of a phosphor magnified many thousand diameters. The wide variety of particle sizes is apparent.

While super-fines are present in the phosphor before milling, they are also created during milling. Here the relative quantity of coarse particles and the hardness of the phosphor particles will influence the production of super-fines. During milling, all particles are broken to some degree even though most of the work is done on the coarse particles. Thus, milling will decrease d_{op}, the optical diameter, and will also increase σ, the spread of the distribution. The overall result is an increase in β. This increase in β varies with the hardness of the phosphor particles, so that different phosphors may have

Figure 7. Electron microscope photograph of a halophosphate phosphor. Length scale shows equivalent length of 1 micron.

about the same β values before milling and widely different β values after milling for the same length of time, as seen in Fig. 8. Therefore, the use of a standard milling time will result in considerable fluctuation in β and in lamp performance. This has been confirmed experimentally in lamps and further data is in preparation.*

It has been found experimentally that presence of as little as 1 per cent of coarse particles over 40 microns can be detected as an appearance defect. Considerable milling is needed to remove this defect with consequent increase in super-fines. To eliminate these super-fines, then, it would be logical to remove the material responsible for their formation. These are the coarse particles. Tests were made on phosphor from which all the particles larger than 30 microns had been removed. It was found, however, that a considerable amount of 0-3μ material was still present, produced by the prior treatment of the phosphor. It was apparent, therefore, that both the $>30\mu$ and $<3\mu$ material would have to be removed.

Several methods for obtaining this separation were tried. One method was to mill to the desired upper limit and then remove the super-fine fraction from the suspension by such methods as elutriation or by centrifuging. These methods produced the desired cut in particle sizes, but the required milling reduced the average diameter more than was desirable; *i.e.*, β values were still rather high.

It was found that an air classification on the dry unmilled phosphor gave the desired cuts. In addition, it allowed great flexibility in cut points to be obtained with ease. The apparatus most suitable was found to be an Alpine Microplex Air Classifier. A standard cut procedure was established to provide phosphors having a range from 3-30μ. Using such phosphors, studies were then made to determine the influence of the particle sizes on lamp performance.

To confirm the theoretical effect of super-fines being responsible for low lamp efficiency, cuts were made at 0-3μ, 0-30μ, 3-30μ with an unclassified control. Fig. 9 shows the particle size distribution and calculated β value for the four cuts, after milling as needed to give proper coating characteristics. The milling time was extremely short except

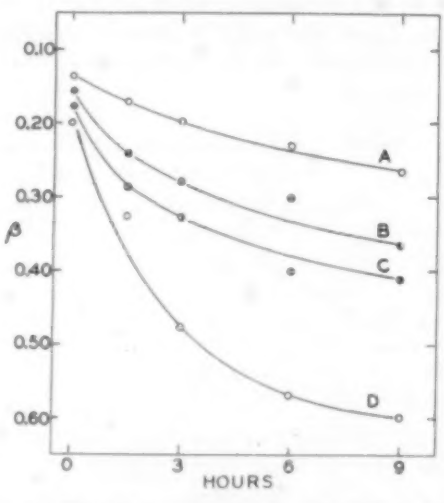

Figure 8. Changes in scattering constant with milling time for various halophosphate phosphors.

*A paper by H. H. Homer and R. F. Quirk, in preparation for the *Journal of the Electrochemical Society*, will give detailed data.

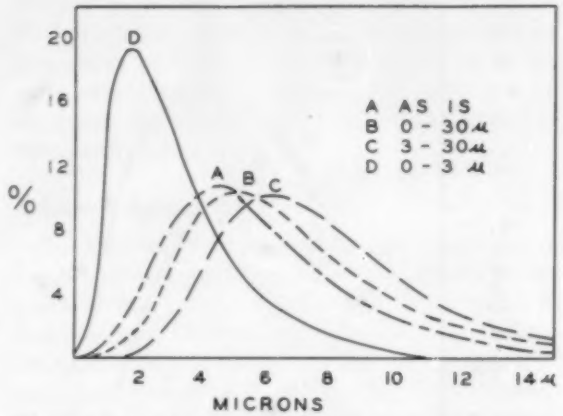

Figure 9. Particle size distributions for various particle size cuts of a halophosphate phosphor. Only cut A has been milled.

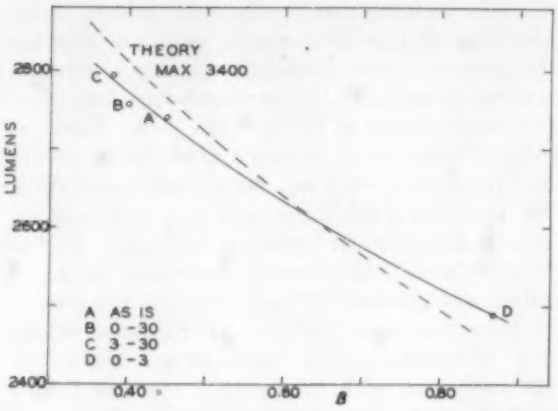

Figure 10. Relationship between the lumen output and the scattering constants for various particle size cuts of a halophosphate phosphor.

for the "as is" material. If the theory is correct, the order of increase in lumen output, based on the β value, should be 0-3μ, unclassified, 0-30μ, and 3-30μ. The results of such a test are shown in Fig. 10. The dotted line on the figure represents a calculated curve where a maximum value of 3400 lumens is assumed for an efficiency of 1.00 and the data of Fig. 4 used for E at various β values. The excellent agreement with the predicted values shows the interrelationship between the amount of super-fine particles present, the β value, and the lumen output of the lamp. Initial lumen values are shown to avoid the additional complications arising from the effect of the first term of the well-known Butler-Lowry Maintenance Equation.

During the study of these cuts, an additional advantage to the removal of the fines, not predicted from the theory, was observed. The maintenance of the lamps improved as the percentage of the super fines decreased. In the lamp series of Fig. 10, for example, at 500 hours the loss in lpw went from 5.4 for the 0-3μ cut to 3.4 for the 3-30μ cut. This poor lumen maintenance can be attributed to increased absorption of deleterious materials by the larger surface area of the super-fine particles.

A series of runs were made reducing the top cut from 30μ to 25μ to determine the effect of the larger particles on lamp performance. Little difference could be detected between the 25 and 30μ cuts, but in each case the cuts with the 3μ material removed were 1-3 lpw brighter than the cuts containing the super-fines and the maintenance was 1-2 lpw better.

A further series was run in which a succession of cuts for removal of super-fines at levels approximately 3, 4, and 5μ were made. Little change in the β value was observed and all lamps in each series had essentially the same lumen values. From these results, it was concluded that the particle sizes having the greatest influence on the β value, and hence on the lumen output, lie below 3μ.

The results of the tests conducted up to this point had confirmed the dependence of lumen output on the β value, as influenced by the presence of the $<3\mu$ material. But since both d_{op} and σ determine the value of β, it is possible to have numerous combinations of the two values which will result in the same β. A further proof of the validity of the theory would be to prepare various cuts from the same phosphor that would result in the same β and to determine if lamps prepared from these cuts would have equal lumen outputs. In Table IV is shown a series of such cuts.

Of particular interest are the samples 1-4 where d_{op} has varied from 7.0 to 4.8μ and the σ's have gone from 1.60 to 2.62. If the theory is valid, all four sets should have essentially the same lumen values which they have. In addition, it can also be predicted that phosphors having equal d_{op}'s but different σ's will give a higher lumen reading for the higher σ since this leads to a lower β value. Such is the case in samples 4 and 5 and again the lamp results confirm the predictions. Over the whole test the lumens have followed the predicted relationships to their β's, *i.e.*, lower β's, higher lumens.

One standard procedure for lamp manufacturing

TABLE IV—Optical Constants and Lumen Output of Various Phosphors.

Sample	d_{op}	σ	β	Lumens
1	7.0μ	1.60	0.38	2767
2	6.3	1.91	0.38	2768
3	5.6	2.30	0.38	2770
4	4.8	2.62	0.39	2760
5	5.0	1.92	0.48	2681
6	4.1	2.05	0.57	2584
7	3.6	2.33	0.58	2587
8	3.6	2.05	0.60	2590

has been to determine the optimum coating thickness for each type of phosphor, setting a value for the optimum transmission of visible light and then coating all bulbs to this transmission. This practice was followed in the previous tests. However, as previously stated, optimum transmission should be a function of the β value of the coating solution. The lower the β value, the higher the coating transmission should be for optimum brightness. To test this prediction, two coating solutions having β values of 0.195 and 0.48 were prepared and a series of bulbs coated to different transmission values. Fig. 11 shows that the results of this test follow the prediction with the lower β coatings having both the higher lumen values and a higher value of transmission, T_1°, for optimum lumens. The upper curve peaks at 3040 lumens for the 0 hour data. This results in lamps with 74 lpw at 100 hours.

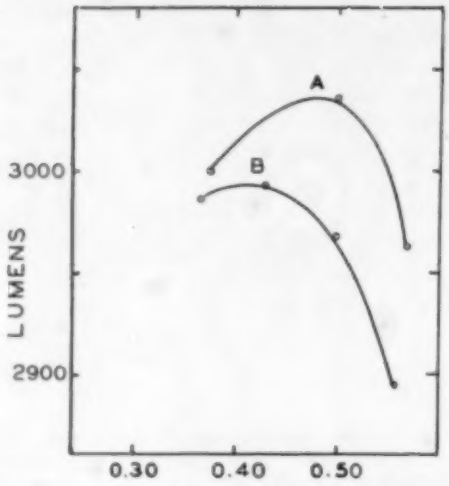

Figure 11. Lumen outputs of lamps made with varying coating transmissions for the different scattering constants. Curve A: $\beta = 0.195$. Curve B: $\beta = 0.480$.

Discussion of Results

From the results of the above studies, the loss of lumen output experienced when phosphors are milled can be explained as follows:

The presence of a quantity of super-fine phosphor particles formed during milling causes a loss in ultraviolet energy by scattering a portion of the energy back into the arc where it is lost by reabsorption. If the coarse particles requiring milling are removed, a definite improvement in lamp performance can be achieved by the prevention of the formation of additional super-fines with milling. An additional improvement in lumen output is possible if super-fines present in the phosphor before milling are also removed. Experience to date has indicated that the coarse cut should be made at about 30μ and the fine cut at about 3μ.

From the particle size distribution of a phosphor, measured on an optical basis, a scattering constant, β, can be calculated which will indicate the relative lumen output of a phosphor. By manipulation of the particle size distribution to give lower values of β, improvements in the lumen output can be achieved. If the β value of a phosphor is known, further improvements in lumen output are possible by adjusting the coating transmission to the optimum value.

When the β value is kept low by selective classification of the phosphor, an impressive improvement in lumen output results. For the past ten years, from 1948 when the halophosphate phosphor was first introduced commercially up to the past year, improvements in lumen output have been in small increments averaging about 1 lpw per year. Now with the use of selectively classified phosphors, a 6 lpw gain has been achieved, bringing the 40-watt white lamp to 74 lpw at 100 hours.

Use of these new manufacturing methods, which allow tailor-making of particle size cuts, in combination with optimized coating transmissions, has allowed still higher lumen outputs to be achieved and efficiencies in the range of 75-80 lpw at 100 hours have been reached. Changes in lamp design parameters give additional gains in efficiency to levels of 80-85 lpw.

Summary

A theory relating the efficiency of fluorescent lamps to the optical properties of the phosphor coating has been developed. This shows that the major controlling factor in lumen efficiency is the reflection of ultraviolet energy from the phosphor back into the arc stream. The amount of this reflection is dependent on phosphor particle size and is determined by a scattering constant, β, whose value is derived from the particle size distribution of the phosphor. Predictions of lamp performance, based on the calculated β values for phosphors, have been substantiated by lamp tests.

It has been found that phosphor particles below 3μ, present in the phosphor as received, or produced by mechanical reduction of oversized particles to achieve proper coating characteristics, lower the lumen output of the lamps. Removal of both the oversized and the less-than-3μ particles leads to improved β values and yields higher lumen outputs with improved maintenance. This has made possible the production of 74-lumens-per-watt, 40-watt white lamps.

In addition, use of the finding that phosphors of different β values require different coating transmissions for optimum lumen output has given

further gains and has lead to efficiencies of 75-80 lpw. These gains have been accomplished by changes in phosphor and coating alone. If, at the same time, changes are made in the lamp arc parameters, the output of 40-watt white lamps has been increased to 80-85 lpw.

Acknowledgements

The authors wish to express their appreciation for the aid received from various members of the staffs of the Design Engineering Department at Danvers and to Divisional Engineering Laboratories at Salem. In particular, Mr. R. F. Quirk of the Danvers staff and Dr. Martha J. B. Thomas of the Salem staff, contributed valuable experimental data.

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DISCUSSION

C. H. HAAKE:* The authors of this paper are to be complimented for having so well combined theory and experiment to prove the effect of phosphor particle size on lamp efficiency. Since Ouweltjes at Philips in Holland, in the paper cited by the authors, reported a rather high gain in lamp efficiency which Ouweltjes attributed mainly to an increased particle size of the phosphor in the coating, we carried out some studies similar to, although by far not as extensive as, those of Dr. Butler and Mr. Homer. We too based our theory on Schuster's equations, although we realized that in the wavelength range of 2537A these equations may fail to hold for halophosphate phosphors since Schuster's equations are rigidly applicable only for weak absorption. However, Dr. Butler's and Mr. Homer's experiments bear out the validity of the assumption that at least the trend of the Schuster equations, *e.g.*, the $R(\beta, \mu, t)$ relationship, would continue to hold into the range of high absorption.

In essence the authors' Equation (8),

$$E = T_\infty^{\,v} \times A_1^{uv}$$

is the same as ours, although we preferred to discuss it in its original form

$$E = T_\infty^{\,v} \times \frac{A_1^{uv}}{1 - R_1^{uv} R_2^{uv}}.$$

With a value of R_2^{uv} of about 0.65, as given by Ouweltjes, and $R_1 \gtrsim 0.2$, the denominator should not be set equal to unity. By doing so one loses, in the discussion of E, the interesting effect of R_2^{uv} on the particle size dependence of the lamp efficiency.

This is illustrated in Fig. A, which was derived from a theoretical discussion of E. It shows the per cent increase of E with increasing average particle size d_{op}, using the effective reflectance of the discharge, R_2^{uv}, as a parameter [$\mu^v = 10^{-2}\ cm^2/mg$, $\mu^{uv} = 0.7\ cm^2/mg$, $R\infty^v = 0.80$, $R\infty^{uv} = 0.20$, $K^v\ (d_{op} \sim 8\mu) = 0.09\ cm^2/mg$, and $K^{uv}\ (d_{op} \sim 8\mu) = 1.05\ cm^2/mg$]. The curves show the increase of E under the assumption that the density of the phoshor layer is such that the transmittance for the ultraviolet radiation, T_1^{uv}, is always 0.02. As can be seen, the effect of R_2^{uv} on E is rather strong. If one is to vary the characteristics of the gas discharge in the lamp, R_2^{uv} will also change and thus the particle size effect on E may either be diminished or accentuated, as the case may be. A proper knowledge of this interrelationship might help in choosing the correct gas discharge conditions for a phosphor-coated lamp.

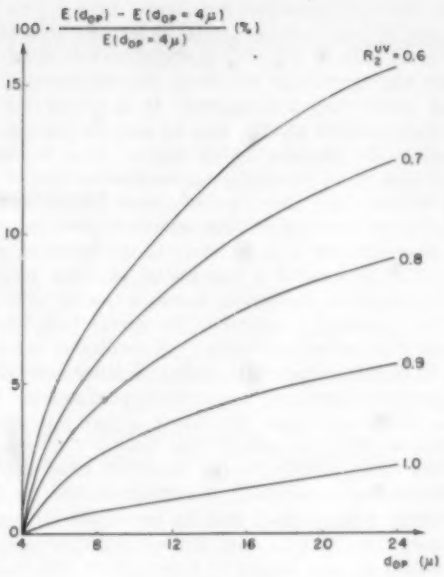

Figure A.

I would like to ask a question of the authors. What were the increases of phosphor weight per lamp for the highest gains in efficiency obtained by particle size control?

W. C. MARTYNY:* The necessity for classifying calcium halophosphate phosphors has been recognized for a number of years. In fact, at the present time practically all fluorescent lamp companies classify their phosphors to some extent. The authors of this paper have presented an interesting theory to account for the performance of various particle distributions. In general, there is no doubt that the optical characteristics of the extremely fine particles adversely affect the lamp performance. However, after reading the data and conclusions, several questions arise.

As a general item, we would be interested in the method used for determining particle size. The same material gives various answers, depending upon the assumptions made in any particular method. We use a modification of the National Bureau of Standards Pipette method which involves the assumption that the particles behave like spheres in following Stokes' Law. It should be noted that when we speak of particle size we are not designating single crystals, but rather aggregates of many-sized crystals. For example, we

*Westinghouse Electric Corp., Bloomfield, N. J.

*General Electric Co. Lamp Division, Cleveland, Ohio.

find that the very large-sized aggregates have a very high percentage of "super fines" attached to their outside surface. During milling, these fine particles are torn loose from the large aggregates and will lower the brightness of the phosphor unless they are removed. It is largely for this reason that particles greater than 30 microns are removed. In addition, the phosphor, when applied to a fluorescent bulb, is made up of all-sized particles piled on top of each other. In view of the above, it would seem difficult to ascertain the optical qualities of these composite particles.

The other question is in reference to the following statement: "The presence of a quantity of superfine phosphor particles formed during milling causes a loss of ultraviolet energy by scattering a portion of the energy back into the arc where it is lost by absorption." According to the paper this is "the major controlling factor in lumen efficiency." Investigations carried out in our laboratory seem to point to some other explanation. Dr. Kenty is very interested in this problem. His data indicate that most of the impinging ultraviolet energy never gets very far away from the phosphor. He estimates that only about 7 per cent of the ultraviolet energy reflected back into the arc is lost. It appears more likely to us that the fines are bad either because they suffer unduly in lamp making or because they trap light.

LUKE THORINGTON:* The authors have made a substantial contribution to our understanding of fluorescent lamps and certainly deserve our high commendation. They have also demonstrated solid practical achievements based on their theoretical studies.

Since the important factor involved here seems to be absorption by the arc stream of 2537A exciting radiation backscattered by the phosphor layer, I wonder if the authors could supply more information regarding the absorption coefficient of the arc stream (mercury vapor at 40C) for this radiation? Were any independent measurements of this absorption made? Also, it would seem that mercury vapor would be found distributed not only in the arc stream but throughout the porous phosphor layer. Then, instead of basing calculations on particles surrounded by a non-absorbing medium (air in the case of spectrophotometric measurements), one would have to consider them as being suspended in a highly absorbing medium (*i.e.*, absorbing for 2537A). The net effect of the super-fine particles would still be to increase absorption of the ultraviolet by mercury vapor, but *not just back-scattered ultraviolet*. Would the authors expect $R \infty$ for 2537A to be different in Fig. 5 if the phosphor samples were permeated with mercury vapor at the time of measurement?

Have any measurements of quantum efficiency been made on the samples of Tables III and IV? It would be interesting to compare these since, if all the samples had the same values, this would further support the theory presented.

While a lamp coated with particles coarser than 30 microns may not be acceptable in terms of appearance, it would nevertheless seem justifiable to make such lamps in order to see how high one can go in efficiency, since β would be correspondingly smaller. Have the authors done this?

Further, have any other phosphors been studied besides the halophosphates; for example $MgWO_4$, which is usually synthesized as a very fine powder but which has been considered by many to have almost 100 per cent QE?

Finally, I would like the authors to explain why they have considered the scattering constant to be independent of wavelength. It is my understanding that for particles of size less than about ten times the wavelength of the incident energy, viz., $<2.5\mu$ in the case of 2537A, the scattering (which is mainly in the forward direction) does vary with wavelength.

K. H. BUTLER AND H. H. HOMER:* All of the discussers have stressed the crucial point of absorption of the reflected ultraviolet by the arc stream. This absorption is very difficult to measure and we cannot give any new data at present. However, we believe that Ouweltjes' estimate of 35 per cent loss by absorption, quoted by Mr. Haake, is more reliable than Dr. Kenty's figure of 7 per cent, quoted by Mr. Martyny. Considerable work done by paper and paint manufacturers on the absorption and scattering of light by absorbing particles has confirmed the validity of Schuster's equations even for cases of strong absorption.

We considered presentation of the equation used by Mr. Haake in which the value of R_2^{∞} is explicitly included but felt this would confuse the effect of particle size. Assumption of various values of R_2^{∞}, in effect, compresses the efficiency scales of Figs. 3 and 4 and pivots the line in Fig. 4 around $\beta = 0$. If R_2^{∞} is 0.00 and E is 0.72, then increasing R_2^{∞} to 0.40 will raise E to 0.78 and raising R_2^{∞} to 0.80 will give $E = 0.88$. The coating thickness for optimum efficiency is independent of the value used for R_2^{∞}.

The detailed calculations by Mr. Haake are of interest, but we feel that the ratio u^{∞}/u° which he used is too low and that the value of E° is close to 0.90.

We cannot agree with Mr. Martyny's statement that "all fluorescent companies classify their phosphors to some extent." There is no published information to indicate that this is true and certainly lamp performance data of other manufacturers, over the last ten years, have not shown the gain of 6 lpw which we have found possible with selective classification. With such classification the need for milling is reduced and super-fines are not torn loose from aggregates to which they may be attached. Our method for particle size determination was fully described in Reference 6 and the method of using this data can be seen in Fig. 2. Mr. Martyny's suggestion that "the fines are bad, either because they suffer unduly in lamp making, or because they trap light" is hardly a scientific statement and therefore difficult to comment upon. The "effect of lamp making" might mean decrease of the ultraviolet absorption coefficient, while "trap light" might mean increase of the visible absorption coefficient, but these are inferences from a vague statement. We cannot agree with this statement of reasons for the bad performance of super-fines.

Mr. Thorington has raised an interesting question on the effect of mercury vapor distributed through the porous phosphor layer to which we cannot give an answer without further study. In our paper, we calculated the light output of 3500K white halophosphate to be 95 lpw, while the experimental data on classified phosphor gave up to 80 lpw. This difference of 15 lpw needs explanation and a clue may be found in Mr. Thorington's question. Because of the effects of particle size discussed in our paper, we feel that all past measurements of quantum efficiency are suspect and that new studies will be needed to establish correct values. As yet, there are no new data available on quantum efficiency.

As to Mr. Thorington's specific questions, $MgWO_4$ reflects very little 2537A radiation, even though its particle size is smaller than halophosphate, and therefore its efficiency in lamps is high. The scattering efficiency of small particles is nearly constant down to a diameter equal to the wavelength, after which it falls off rapidly so that down to 0.5-micron diameter scattering efficiency is independent of wavelength.

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Views and Opinions

Designing Prismatic Profiles

As a developmental designer and lighting consultant with responsibility for designing prismatic Perspex (acrylic sheet) covers for street lighting fittings, I have studied everything I could find relating to the refraction of light in different media. As a result of these studies, I discovered, in my old schoolbooks, the same method for finding the path of a light ray in a given prism as was recommended in the "IES Guide to Design of Light Control—Part II—Design of Reflector and Optical Elements," published in December, 1959 Illuminating Engineering, pages 778-786.

Since I wanted to know how a prism should be designed to produce a given path of light and this method seemed rather complicated, I have tried to find a simpler way of designing prismatic profiles for a given plastic or glass bowl and a given position of the light source, considered as a point.

For me, the simplest method for finding this path of light is to make a graphic solution of the basic refractions of the incident and emerging light in one drawing (Fig. 1). For a given prism β, it is very easy to find the different angles of δ for different angles of i. If a degree scale is made in the M circle, the different positions of line intersections are quite easily read (Fig. 2).

Results obtained with this method were used to produce the diagram in Fig. 3. The relation is shown between the angles i, β, γ and δ. Fig. 3 is drawn for media having an index of refraction of $M = 1.5$. (The indices of refraction for glass and Perspex are very close to this value.) Using this diagram it is possible to find:

(1) Angle β, if angle i and angle δ are given (the case when the prisms from which the light emerges are on the outside of the bowl and the light source is on the smooth inside).

(2) Angles β and i, if angles γ and δ are given (the case when the prisms and the light source are on the prismatic inside of the bowl and the light emerges from the smooth outside).

Because the reflection losses for different angles are incidence are known, we know that, for instance, with acrylic sheet (Perspex) the losses are: 5 per cent for $i = 0$ to 45 degrees, 10 per cent for $i = 60$ degrees, 20 per cent for $i = 70$ degrees, 30

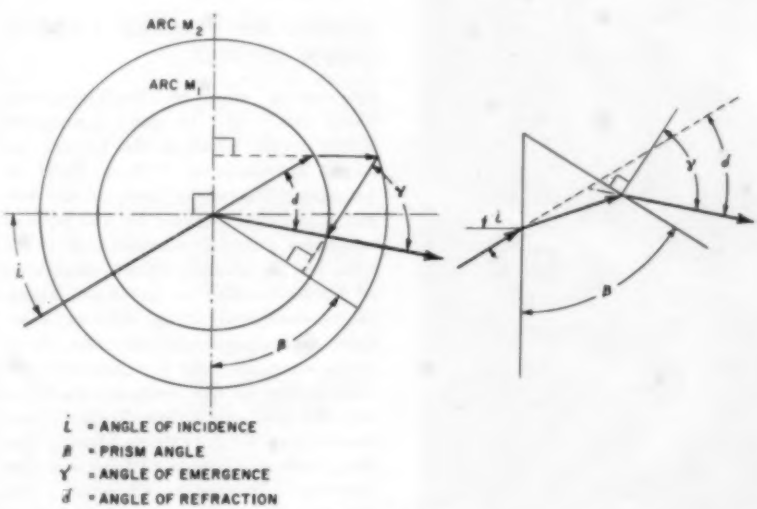

Figure 1.

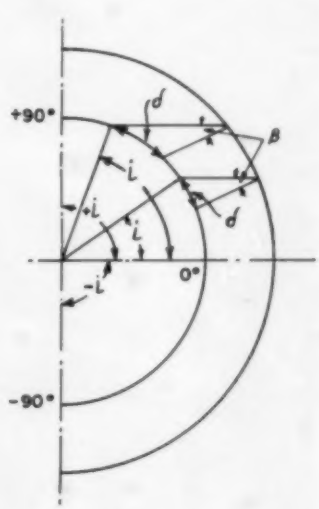

Figure 2.

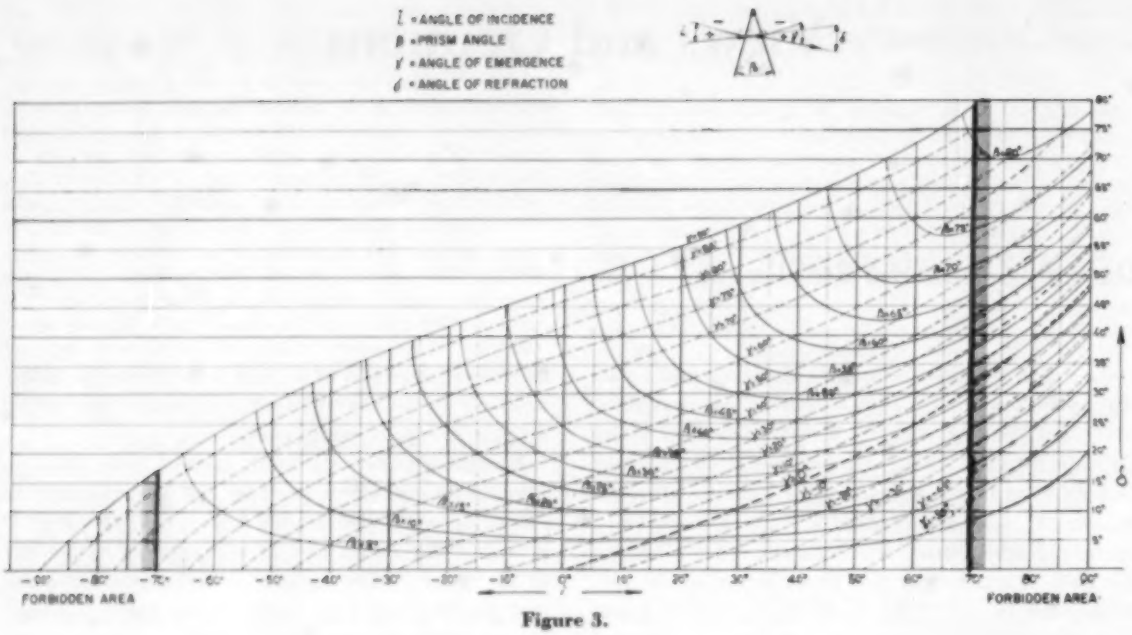

Figure 3.

per cent for $i = 76$ degrees, 40 per cent for $i = 80$ degrees. From this, we can conclude that $i<60$ degrees is preferable and $i>70$ degrees should be avoided. If a line of demarcation is drawn on the diagram at $i = 70$ degrees and $i = -70$ degrees, the forbidden area is easily seen.

For greater angles of δ the refraction/reflection systems recommended in Section 3.4 of the "Design of Light Control—Part II" should be used. However, it should be possible to make a diagram for this condition, too.—*M. J. Gordijn, Illuminating Engineer, Rotterdam, Holland.*

Modern Air Terminal Lighting Greets Jet Age

Continuous rows of flush-mounted, "very thin" (3-1/16-inch) luminaires create traffic lanes at the United Air Lines Terminal at O'Hare Field in Chicago. The lobby area of the terminal building, lighted by 430 40-watt two-lamp luminaires, mounted at 14 feet, has an average illumination level of 60 footcandles to speed the hurrying passengers. Fifty 40-watt four-lamp units, suspended over the check-in counter at eight feet provide 120 footcandles on the counter. Architect for the job was Ralph Stoetzel; contractor was W. J. O'Brien Electric Co., Inc., both of Chicago. *Photo and data courtesy Monsanto Chemical Co., Plastics Division, Springfield, Mass.*

Recommended Practice for Airport Service Area Lighting

Prepared by the Subcommittee on Service Area Lighting of the Ground Lighting Committee of the Aviation and Signal Committee of the Illuminating Engineering Society

Foreword

Considerable effort has been expended by industrial and governmental authorities in analyzing and solving the problems relating to airport approach, runway and taxiway lighting. Yet relatively little has been done to solve another problem which has a direct bearing on the success or failure of the airport's operational lighting system. This is the question of airport service area lighting.

According to a poll of major airline operators, most believe the lack of proper ramp or loading apron lighting at many existing airports is costing them money and is dangerous to flight crews, maintenance men and passengers. Many existing service area lighting installations, in short, are unsatisfactory and should be improved, according to airline operators.

Further, the Committee believes initial service area lighting installations made on new or improved airport terminal facilities should be accomplished according to nationally recognized standards for good lighting practice as adapted to this particular task.

It is the purpose of this Practice not only to define the task and somewhat severe limitations usually imposed upon pertinent lighting methods, but also to suggest methods of solving the lighting problems in such ways that service area lighting will augment operational lighting installations, rather than detract from their over-all effectiveness.

The Committee believes that the publication of this recommended approach will provide a valuable guide to those involved in airport planning, such as architect-engineers, lighting consultants, government supervisory personnel, airline operators and airport management. Installations made according to the recommendations should eliminate much of the hazard and lost time attributed by airline operators to poor service area lighting.

Airport Service Area Lighting

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1. Definition and Scope

(a) The term "service area," "loading ramp" or "apron" should be understood to be an all-inclusive one. It refers to every operational outdoor area not directly involved in aircraft landing and taxiing procedure. It involves areas into which aircraft would normally be expected to move under power or by towing, but usually does not include strips reserved for the passage from one area to another of aircraft under power or in tow.

(b) The "service area" for which lighting methods are described in this Practice is defined as only that portion of the airport ramp or loading area where the aircraft may be temporarily parked for loading and servicing as outlined in Section 2. This service area is adjacent to the airport passenger or freight terminal or "loading finger" area, or to the maintenance and storage hangar areas, following the linear outline of these buildings or areas. This area is not normally used for maintenance and repair work.

(c) Depth of the area or corridor so constituted is determined largely by the diameter of the aircraft parking circle of maximum area, and by the amount of space necessary to taxi the aircraft safely into this position.

(d) Minimum corridor depth for which reasonably uniform illumination should be provided is about 200 feet; maximum depth ranges from 200 to 300 feet out from the entrance and exit gates of the terminal facility. Since all seeing tasks of any degree of complexity are performed within this corridor, it is considered unnecessary and uneconomical to attempt uniform lighting of the entire existing ramp or apron area. Accordingly, no further consideration is given to over-all apron lighting within the scope of this report.

2. Service Area Seeing Tasks

2.1—General—(a) Primary functions of the service area lighting installation are: (1) to enable the pilot to guide (taxi) his aircraft into final position for loading and service; and (2) to provide lighting suitable for personnel to perform the functions of loading and unloading passengers and cargo, loading fuel, and performing other apron service functions.

(b) The following Sections, 2.2 to 2.10, list functions which are to be effectively accomplished within the service area and some of the considerations which influence the illumination of these functions during operations performed at night.

2.2—Aircraft Taxiing—The pilot relies mainly on fixed lighting when taxiing to his ramp position. Uniform illumination of the pavement within the service area and elimination of excessive glare are major requirements.

2.3 — Fueling Operations — (a) For fueling operations, wing areas should be lighted. Jet aircraft, as a rule, are refueled from the underside of the wing. Piston-engined aircraft, as a rule, are refueled from the top side of the wing.

(b) In addition, underground fueling pits at many airports should be provided with lighting to enable the operator to watch the pumping operation and the hose reels.

2.4—Baggage Loading and Unloading—Illumination should be provided at the side of the aircraft facing the loading gate to permit the reading and checking of cargo lists, etc. Either vertical or horizontal illumination is suitable for this task, as the reading matter can generally be oriented to best utilize the available light.

2.5—Mechanical Check—This includes the checking of the aircraft's parts while it is parked on the apron. Illumination is needed to aid in making this check.

2.6—Passenger Loading and Unloading—(a) Normally, for passenger loading and unloading, it is not as important to have a great deal of light as it is for some of the other operations. However, it is psychologically advantageous to provide enough light to prevent the passenger from having to grope his way up or down the loading ramp, and to prevent difficulty in his actually locating the exit from the service area to the terminal building.

(b) In gathering data on this operation it was found that, at some airports, the aircraft are parked double. The light that would normally reach the second aircraft is, of course, obscured by the first aircraft, thus making the "seeing task" very difficult. Luminaire mounting heights on the order of 50 feet minimum are generally required to provide illumination at the second aircraft at those locations where aircraft are parked double.

2.7—Operation of Air-Conditioning and Fueling Trucks—Illumination should be such that the operators can see what they are doing without having to use truck headlights.

2.8 — Self-Propelled Power Unit Trucks — Aircraft, when parked on the apron, use these trucks to provide power for interior lighting, etc. Illumination is needed to facilitate the making of connections.

2.9 — Engine Maintenance and Repair—Occasionally, quick repairs are made on engines while aircraft are parked on the ramp. Good lighting is obviously needed for this type of operation. Supplementary illumination in the form of portable lights, or vehicle mounted spotlights, etc., is generally required in addition.

Approved by the Council of the Illuminating Engineering Society, February, 1960. A Transaction of the IES.

Figure 1. Incandescent luminaires on 150-foot spacing and 50-foot mounting height (fourteen 500-watt units per pole) provide the general and direct lighting at this airport.

2.10 — Parking Areas for Ramp Service Vehicles—The apron lighting installation should be designed to light areas adjacent to the terminal building or finger where ramp service vehicles are parked.

3. Considerations Affecting Location of Service Area Luminaires

(a) Limitations governing luminaire mounting heights in the vicinity of the service area are established, for the most part, by the Federal Aviation Agency's Technical Standard Orders.

(b) As an example, the limits established by TSO-N18 (dated July 30, 1952) restrict obstruction heights to a ratio of 1 in height to 7 in horizontal distance from the nearest edge of the runway. For instrument approach zones, these are 1000 feet wide.

(c) For non-instrument approaches, the requirements are less rigid, and, for the purpose of this report, approach zone widths will be approximately 500 feet wide.

(d) These restrictions should be taken into consideration when designing service area lighting layouts, so that luminaire standards and poles do not protrude into the line of sight between the control cab and the service area, taxiways, runways, and so control tower vision is not impaired by glare from the service area lights.

(e) Location of service area luminaires would provide the most effective utilization of light if located at the protected edge of the service area, whether this be a fence, such as is often used, or actual exit and entrance portals to the terminal building itself, or loading ramps connected to them.

(f) Luminaire standards located and limited as to height, in accordance with the above, may still be considered hazardous for aerial navigation. The local Federal Aviation Ageney lighting engineer should be consulted in every case as to the requirements for installation of suitable obstruction lighting equipment on luminaire standards.

(g) It is essential to note that luminaire poles are not prohibited from the service area, and specifically, that these poles may be of any particular height within limits established by FAA.

Figure 2. An example of a fluorescent floodlighting installation. The units, which are on 25-foot spacing, utilize 1000-ma lamps.

4. Factors Influencing Lighting Design

4.1—General Lighting—(a) It is essential to provide at least minimum quantities of light flux for safety and efficiency in conducting all tasks within the service area. These seeing tasks are of varying difficulties, accordingly requiring more or less light.

(b) The approaching pilot should have sufficient illumination to enable him to identify his destination and steer clear of obstructions. This can be accomplished with relatively low levels of light, if glare and high-brightness differences are minimized. General lighting permits the pilot to locate dark objects, such as moving service trucks, pedestrians, and other aircraft, against the relatively bright background created by the general lighting system.

(c) Adequate illumination for this seeing task is obtained by employing horizontal lighting levels upon the pavement surface of not less than 0.5 footcandle average *maintained* in service. Lighting levels in excess of 1 footcandle are sometimes employed. These higher levels of illumination, due to a greater number of lighting units and closer spacing, serve to provide a higher quality of lighting, and general increased visibility.

(d) In order to provide optimum visibility for the approaching pilot, it is essential that the service area pavement be lighted uniformly within a 4 to 1 uniformity range (average to minimum). This may be done if suitable attention is paid to the types of light sources, and their optical systems, and location of equipment with relation to the service area. Above all, attention should be paid to the reduction of *disability* and *discomfort glare*.

4.2—Direct Lighting—(a) Practically every other visual task performed upon the service area employs light reflected from the working surface. This requires direct illumination of relatively high levels. Surfaces range from horizontal to vertical. Average illumination levels of at least 2 footcandles *maintained* in service are normally considered necessary for illumination of objects where fine visual acuity is not essential. The major visual tasks on the service area fall within this category. Most of the operations requiring direct illumination take place at or near the side of the aircraft facing the loading gate, or else underneath the aircraft. Luminaires mounted at the lower mounting heights have some advantages in the ability to provide illumination under the aircraft.

(b) Many of the objects receiving direct illumination are highly specular, such as the aircraft, service vehicles, etc. Specular surfaces can best be illuminated by having the light come from a large number of evenly distributed sources. There will be a considerable reduction in shadows also if each object within the service area is illuminated from more than one direction.

4.3 — Combination of General and Direct Lighting — The minimum lighting installation should be capable of providing an average level of illumination of 0.5 footcandle, horizontal (*maintained* in service), over the surface of the entire area, for the benefit of the approaching pilot; while providing levels of 2.0 footcandles, average vertical, at the near side of the aircraft for additional visual tasks performed in connection with servicing of the aircraft.

5. Acceptable Methods of Lighting Design

5.1—General—(a) The most important consideration in designing the lighting installation, aside from the essential nature of providing uniformity of illumination of the service area pavement, is that of *keeping glare to a minimum*. Glare from bright sources in the line of sight is particularly troublesome to the control tower operators and pilots of the aircraft taxiing in the general vicinity, as well as to service personnel, passengers, and, in short, everyone making use of service area and service area facilities.

(b) Factors affecting glare are: (1) location of luminaire or luminaires; (2) direction of light beams, and (3) type of light source and luminaire.

5.2—Luminaire Mounting Height (a) At many airports, glare has resulted from the practice of installing high-brightness luminaires at low mounting heights. In many cases (and sometimes without proper exploration of the situation) mounting luminaires at greater mounting heights has been considered hazardous to aerial navigation. It should be emphasized, however, that reduction of glare may often be more important than restrictions on mounting heights.

(b) Since they are located at the

Figure 3. This mercury installation for the service equipment parking area utilizes 1000-watt street lighting luminaires (equipped with improved-color lamps and special shielding) on 60-foot spacing and at a mounting height of 35 feet.

terminal facilities, the service area lights are normally far removed from approach zones and landing strips. Glare may be reduced by increasing luminaire mounting height within approved limits. Obstruction lights can be used to mark the standards wherever necessary.

(c) Luminaires employing high-brightness incandescent filament or mercury sources are acceptable for service area lighting when mounted at suitable mounting heights on buildings or poles. Mounting heights of these units should be as great as possible, the minimum being not less than 50 feet for floodlights, and not less than 30 feet for street lighting types of luminaires. Lower brightness luminaires, such as fluorescent, may be mounted at heights as low as 15 feet, if proper shielding or diffusion of bare lamp light is employed.

5.3 — Direction of Light — (a) Light should be projected to each plane service area from at least two or preferably more directions. It is recommended that poles or towers used for supporting high-brightness floodlights be located between the individual plane service locations with light being directed from both sides. When fluorescent luminaires are used, generally a large number are required to develop the required illumination levels. Preferably, these should be spaced uniformly in a continuous row rather than grouped in large banks; however, when necessary, they may be arranged in groups spaced 100 feet or less apart.

(b) If aircraft are parked for servicing in double rows, mounting heights should be extended and additional floodlights at the higher level should be assigned to the out-row positions. Where practical, the height should be such that the projected light angle of incidence to the pavement should be about the same as that of the light assigned to the inner row positions. The use of uniformly-spaced, wide-beam floodlights will help to reduce the shadow cast by the aircraft in the "near row" position.

5.4 — Type of Luminaire — (a) Floodlights should be the enclosed type with wide horizontal spread (approximately 100 to 140 degrees). To eliminate an upward component of light it is recommended that high-brightness floodlights be equipped with visors or louvers to reduce glare to landing aircraft and to remove bright objects from the control tower operator's line of vision. Fluorescent floodlights mounted below a 25-foot height should be equipped with shields to prevent direct viewing of the bare lamps from the horizontal direction to reduce the brightness seen by a pilot while taxiing his aircraft into the servicing area (cockpit windows are, typically, approximately 15 feet above ground level).

(b) When additional lighting is required for the service equipment parking area, street lighting type luminaires may be used. As before, attention should be given to proper shielding to prevent glare.

6. Application Layouts

(a) Figs. 4(a) and 4(b) show the methods of lighting service areas at an airport. For ease in defining the aircraft positions, plane position circles are shown. Most of the activity involved in servicing the aircraft takes place within the circle. The area within and between these plane position circles should be illuminated, at

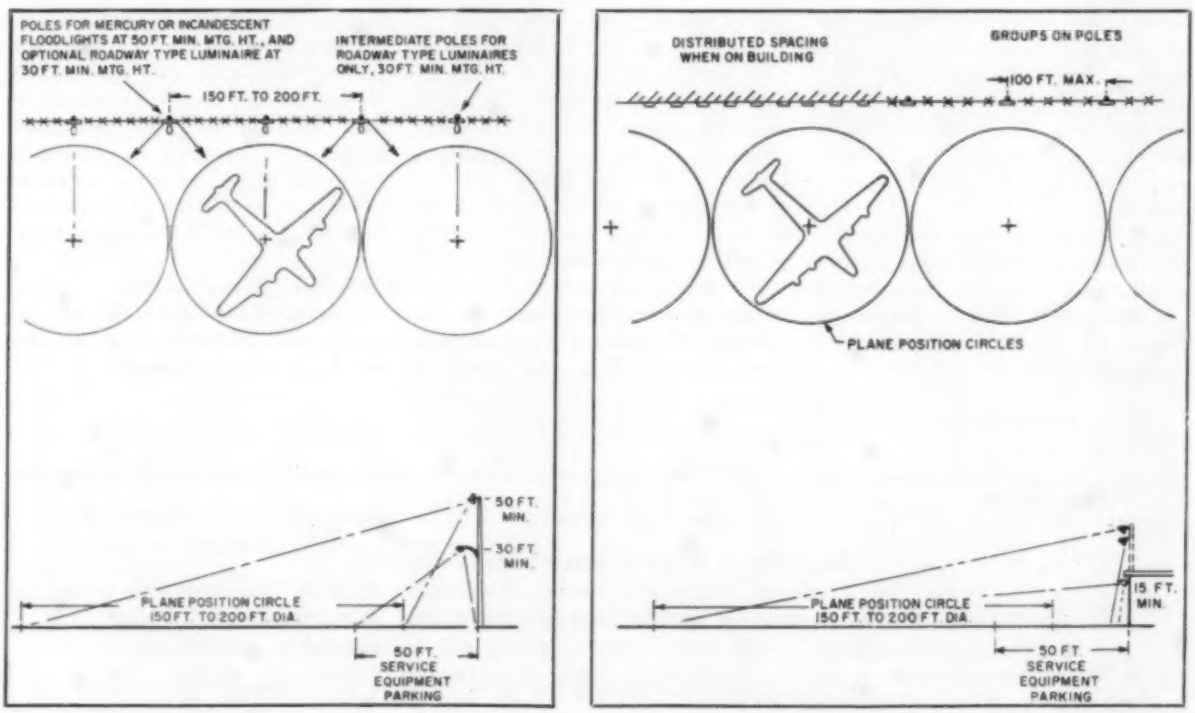
POLES FOR MERCURY OR INCANDESCENT FLOODLIGHTS AT 50 FT. MIN. MTG. HT., AND OPTIONAL ROADWAY TYPE LUMINAIRE AT 30 FT. MIN. MTG. HT.
INTERMEDIATE POLES FOR ROADWAY TYPE LUMINAIRES ONLY, 30 FT. MIN. MTG. HT.
150 FT. TO 200 FT.
50 FT. MIN.
30 FT. MIN.
PLANE POSITION CIRCLE 150 FT. TO 200 FT. DIA.
50 FT. SERVICE EQUIPMENT PARKING
a
DISTRIBUTED SPACING WHEN ON BUILDING
GROUPS ON POLES
100 FT. MAX.
PLANE POSITION CIRCLES
15 FT. MIN.
PLANE POSITION CIRCLE 150 FT. TO 200 FT. DIA.
50 FT. SERVICE EQUIPMENT PARKING
b

Figure 4. (a) Suggested lighting layout when using mercury and/or incandescent luminaires to light airport service area. (b) Suggested layout when using fluorescent luminaires for lighting of service area.

all times, to an average level of 0.5 footcandle, horizontal. In addition, there should be a specific illumination of 2.0 footcandles, vertical, along the line joining the centers of these circles. The lighting may be designed in units for each circle, so that the layouts would apply to any number of service spaces. When designing an installation using fluorescent floodlights, it is generally found that the lights assigned to one circle will provide considerable illumination within adjacent circles; thus the total number of floodlights required may be reduced accordingly.

(b) The area between the plane position circles and the apron limit (service equipment parking area) should be illuminated to an average level of 1.0 footcandle, horizontal. If the higher mounted floodlights do not light this area adequately, then the street lighting type luminaires should be put into service.

(c) The lighting layout may utilize various combinations of luminaires, for example: (1) Fig. 4(a)—Mercury or incandescent floodlights mounted at 50-foot heights to illuminate the service area; plus mercury, incandescent or fluorescent street lighting luminaires to illuminate the service equipment parking areas. (2) Fig. 4(b)—Fluorescent floodlights at any mounting height between 15 and 50 feet to illuminate the service and parking areas. (3) Combination of Figs. 4(a) and 4(b)—Fluorescent floodlights supplemented with mercury or incandescent floodlights with the latter units provided to illuminate more distant portions of the servicing area.

(d) While this recommendation applies mainly to airport passenger terminal service areas, the same layout and illumination levels could apply to hangar apron and cargo (freight) loading areas.

7. Summary of Recommendations

(a) Airport Service Area Lighting should fulfill two basic requirements: (1) Provide satisfactory visibility with minimum glare to the pilot when taxiing to and from the service location. (2) Provide sufficient illumination for fast, efficient and safe service of the aircraft.

(b) For the first requirement, a relatively uniform average horizontal illumination level of 0.5 footcandle should be maintained in service.

(c) For the second requirement, the service area should have an average vertical illumination level of 2.0 footcandles along the center line of the service area (maintained in service).

(d) Arrangement and location of lighting equipment, and minimum mounting heights for equipment, should be as shown in Fig. 4.

8. Special Considerations

8.1—Economic Considerations— **(a)** Circuit arrangements for "general lighting" should be such that they can be operated independently of the "direct lighting," with "direct lighting" energized only when the plane is in servicing position.

(b) The lighting system should be so designed that maintenance expense can be held to a reasonable value. If access to luminaires is difficult, it is most economical to change lamps on a group replacement basis. The cost of replacing lamps in high-mounting-height-luminaires can be significant, thus long-life-lamps should be used. Where possible, the luminaires should be so placed that they will be easily accessible without using special equipment. If the luminaires are mounted on the building, they usually can be placed so that they will be accessible from the roof. Tall poles should be equipped with pole steps for climbing and servicing.

(c) Illumination levels described in this recommendation should be considered *minimum* maintained values for a good lighting job. If the importance or size of the airport justifies a more costly installation, then over-all levels in excess of 5 footcandles may be desirable. Such levels would assuredly meet all the requirements for safety and efficiency. Further, it may be important to airport management to put in higher levels of illumination for impressing the public with the progressiveness and consideration for safety and comfort of those who use the airport facilities.

8.2—Stroboscopic Effect— In the case of either fluorescent or mercury lighting, stroboscopic effect may be undesirable. Reduction of stroboscopic effect can be accomplished by alternating luminaires connected to each phase of a three-phase electrical system, or by using sufficient incandescent lighting in conjunction with mercury or fluorescent lighting in order to overcome stroboscopic conditions.

8.3—Supplementary Lighting— Levels of illumination and methods of obtaining them as set forth in this report are intended to be sufficient and adequate for performing the functions normally carried on in the service area. However, it may be found necessary to have supplementary lighting under certain conditions, such as: (1) where fueling is done from pits, additional lighting localized in the pit for purpose of reading meters, checking hose reels, valves, etc., may be required; (2) for inspection, service or other functions carried on inside the aircraft proper. Here again, auxiliary lighting or portable lights may be necessary.

Reprints — Airport Service Area Lighting

This report will be reprinted in booklet form. Orders should be placed now for delivery when available. Single copies—50 cents; quantity prices will be supplied on request.

Send orders for reprint to Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

A.I.A. File No. 31*f*

INSTALLATION AT WARREN SERVICE CENTER, DETROIT EDISON CO., DETROIT, MICH.

Lighting a Display Shop

LIGHTING OBJECTIVE: To provide lighting for the construction and painting of signs and display material.

GENERAL INFORMATION: This shop, which is irregular in shape as shown in Fig. 2, is approximately 60 feet long by 52 feet wide. The ceiling is of saw-toothed construction in which the bottom is 16½ feet above the floor and the top 25½ feet above the floor. Colors and reflectances are: ceiling, light gray, 34%; walls, light green, 54%; floor, marbelized red tile 15%.

INSTALLATION: After one year of operation, and also one month after relamping, the average level of illumination 3 feet 6 inches above the floor was 150 footcandles. (Most work is performed at this height above the floor.) The lighting is provided by 29 Miller Co. catalog No. IN-2501-08 semi-direct industrial type luminaires with apertures for 25 per cent uplight, arranged in rows on 13-foot centers, 15½ feet above the floor, as shown in Fig. 2. Each unit is equipped with two 96-inch TD-17 extra high output cool white fluorescent lamps.

Brightnesses measured at the same time as the illumination level were: luminaire at 45 degrees, 2000 fL; walls, 25 fL; and floor, 12 fL.

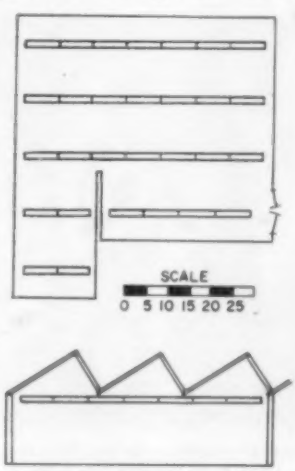

Figure 2. Plan view (above) and elevation (below).

Lighting designed by G. D. Chambers and P. Egigian of Engineering Design, Detroit Edison Co., Detroit, Mich.

Lighting data submitted by R. D. Langenhorst, Detroit Edison Co., Detroit, Mich., as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Series XXV
7-60

A.I.A. File No. 31*f*

Here and There With IES Members

Wesley Nelson (right), first-prize winner of the Allied Arts Competition at Arizona State University, receives award and congratulations from George A. Hill, chairman of Allied Arts activities for Arizona Section. Mr. Nelson's winning entry was a design for a private art gallery.

IES first vice-president Richard G. Slauer (not shown) presented awards to winners in two-section University of Cincinnati Allied Arts Competition, l. to r.: Ronald W. Gell, first prize, Section II; Kuehn Frederick, first prize, Section I; Leonard E. Mankowski, second prize, Section II; Timothy A. Walters, second prize, Section I. Problem was the design of a small museum, with special emphasis on interior and exterior illumination.

Special meeting of the Tar Heel Section on May 23 featured talk by H. Richard Blackwell (second from right) on "Illumination Related To Visual Tasks." Dr. Blackwell is shown here with program chairman George Wilkinson (left), Mrs. Blackwell and Section chairman, Llew Cordle. Prior to program, members gathered at dinner.

Top award winner at U. S. Engineer Research and Development Laboratories, Fort Belvoir, Va., IES Fellow Oscar P. Cleaver (right) receives his eighth "Outstanding" rating in recognition of his work as chief of the Electrical Engineering Department. Presentation was made by Col. H. J. Skidmore, director of the Laboratories.

LIGHTING NEWS

Blackwell and Pritchard Honored by IERI

In appreciation of their valuable contributions to the lighting field, H. Richard Blackwell and Benjamin S. Pritchard were presented on May 16 with Certificates of Distinguished Service by the Illuminating Engineering Research Institute. As Mr. Pritchard has been seriously ill, A. F. Wakefield, chairman of the IERI Board of Trustees and E. M. Strong, chairman of the Research Executive Committee, made the presentation in his room at the Mt. Carmel Hospital, Columbus, Ohio.

Dr. Blackwell and Mr. Pritchard collaborated on the development and application of a method of evaluating field tasks to determine degree of illumination necessary for efficient seeing. Dr. Blackwell applied his knowledge of psychophysics to develop the method while his partner was responsible for the instrumentation and techniques for measuring the tasks. Mr. Pritchard carried out the measurements on a series of interior tasks, and more recently has applied the same technique to the measurement of roadway obstacles under street and highway lighting conditions. In addition, he has made an intensive study of losses of contrast for office and school tasks due to reflections and overhead lighting equipment in the detail and the background of the tasks.

Survey Investigates Decline in Engineering Enrollments

An increased interest by qualified students in other fields of science appears to be one of the factors responsible for the continued decline in freshman engineering enrollments, according to a survey conducted by the Engineering Manpower Commission of Engineers Joint Council. The survey, compiled from statements of 150 engineering deans, also lists concern over the rigors and demands of engineering education and a decrease in applications from students lacking in genuine interest and motivation for engineering as the reasons for the decline.

Schools in the South and Mountain States have been most affected by the downward trend, which started in 1958-59 when freshman engineering enrollments dropped 11.1 per cent. The 1959-60 drop was 3.4 per cent.

The study revealed a critical attitude on the part of the deans with regard to the high school preparation received by engineering applicants. Also noted was a general concensus concerning the need for more effective means of communication between young people and those within the engineering profession.

Copies of the complete report may be secured from the Engineering Manpower Commission, 29 West 39th Street, New York 18, N. Y.

Illini and Housatonic Chapters Chartered by Council

Two more Chapters were added to the rapidly growing IES rolls with the chartering of the Illini Chapter in Decatur,

Illuminating Engineering Research Institute

Certificate of Distinguished Service

presented to

H. Richard Blackwell, Ph. D.

May 16, 1960

CERTIFICATES of Distinguished Service are presented to H. Richard Blackwell (second from right) and Benjamin S. Pritchard by the chairman of the IERI Research Executive Committee, E. M. Strong (left), and the chairman of the Board of Trustees, A. F. Wakefield. Mr. Pritchard was honored as one who, "beyond skillfully fulfilling his research assignments in behalf of illuminating engineering, contributed his ingenuity and inventiveness with wholehearted devotion and magnanimity to the service of this science." Dr. Blackwell's Certificate (above) was awarded "in recognition of his keen understanding, imagination and leadership in applying his broad knowledge of the science of vision to the science of illumination for more efficient seeing in the daily lives of all people."

Ill., and the Housatonic Chapter, Bridgeport, Conn. The action, which took place at the June 17 meeting of the IES Council in New York City, swelled the total number of local IES groups to 94.

Illini Chapter, No. 93, has been operating as the Illini Study Club since the beginning of this year. Official sponsor was the St. Louis Section, with the Chicago Section acting as unofficial co-sponsor. Chairman of the group is Gordon Bonvallet, Illinois Power Co., Decatur; Secretary is Don Weatherford, Engineering Service Co., also of Decatur.

Chapter No. 94, Housatonic, which grew out of the Fairfield and New Haven Counties Study Club, takes its name from the river which flows through the center of the Chapter's territory in southwestern Connecticut. Walter Damuck, Damuck & Painchaud, Architects, Madison, was elected first Chairman of Housatonic Chapter; Court Johannsen, Frank E. Brown, Co., Inc., Branford was chosen as Secretary.

In another symbol of IES growth, the Mother Lode Chapter in Sacramento, Calif. was accorded Section status. Originally chartered in 1947, the new Section has a membership of 63 and an admirable activity record over the past several years.

Lillian Eddy Cited By NY Residence Lighting Forum

At a dinner meeting of the New York Residence Lighting Forum at the Red Barn in Westford, Conn., Miss Lillian Eddy, General Electric Co., New York, was honored for her many years of service to the Forum. A Citation of Achievement, presented by Ruth Lieb, Forum Chairman, was awarded "in grateful appreciation of her outstanding service rendered the Forum since its organization."

During her twenty-four years of Forum activity, Miss Eddy has held several offices, acted as an instructor in residential lighting courses, judged design competitions and served as a speaker at many Forum meetings.

Great Increase in Power Production Predicted by Edison Institute Study

The electricity-producing capabilities of investor-owned utility companies in the United States is expected to nearly quadruple in the next twenty years, according to a report by Allen S. King, president of the Edison Electric Institute and president, Northern States Power Co., Minneapolis, Minn.

A new Institute study on serving electricity requirements in 1970 and 1980 predicted that by 1970 the electric companies will more than double their present power-producing capability, reaching a total of 263,000,000 kilowatts, compared with 127,000,000 kilowatts at the beginning of 1960. By 1980, their capability is expected to reach more than 492,000,000 killowatts, nearly four times today's total, according to the Institute's figures.

The first part of the study on "Meeting Tomorrow's Power Needs" gives national data on the plans of America's electric light and power companies for meeting power requirements in 1970 and 1980. In its second part, the study describes present and future developments by electric companies on a regional basis, dividing the country into eight power supply regions, as defined by the Federal Power Commission.

JOINING city officials, civic leaders and newsmen on nightime aerial inspection tour of Detroit metropolitan area lighting, following presentation of Reader's Digest Public Service Awards, are, l. to r.: Walker Cisler, president of The Detroit Edison Co.; Edmond C. Powers, education director of the National Street and Highway Safety Lighting Bureau; Charles Hepler, Detroit manager of the *Reader's Digest*, and Harold F. Wall, general superintendent of Detroit's Public Lighting Commission.

Reader's Digest Awards Presented in Detroit

The Detroit Edison Co., which planned, developed and installed the modernized lighting for six of the 15 incorporated cities and towns meeting the safety code of the American Standards Association, has received a Reader's Digest Public Service Award in recognition of its accomplishments. A second award was presented to the City of Detroit for its leadership in the modernization of urban lighting.

Detroit Edison president Walker Cisler and Detroit's Mayor Louis C. Miriani accepted the awards at ceremonies held on June 2. Each was also presented with a $250 check for donation to his favorite charity.

Following the ceremonies, *Reader's Digest* invited city officials, civic leaders and newsmen on a nightfall aerial inspection tour of the Detroit metropolitan area lighting program. Accompanying the party were IES members Harold F. Wall, general superintendent of the Detroit Public Lighting Commission; George K. Glass, Detroit Edison's street lighting engineer; and Edmond C. Powers, education director of the National Street and Highway Lighting Bureau.

National Science Foundation Marks Tenth Year

The National Science Foundation, which celebrated its tenth birthday in May, has made 1,809 basic research grants totaling over $49,000,000 during the past year, according to *Engineering and Scientific Manpower*. Since the time of its establishment, the Foundation's activities have jumped from an initial appropriation of $3,500,000 to a current fiscal 1960 appropriation of $152,000,000.

Future plans of the Foundation include the publication, sometime this year, of a revision of the National Research Council's study, "Soviet Professional Manpower," originally published in 1955.

Drop in Engineering Enrollment Attributed to Rising Science Interest

The suggestion that a drift of students from engineering to science may be partially responsible for the decrease in engineering enrollments (see page 9A) has been substantiated by report from a private institution, analyzed in *Engineering and Scientific Manpower*.

The figures for the four academic years from 1956 to 1960 indicate that total enrollment during this period rose 4.5

(Continued on page 15A)

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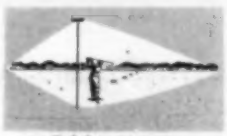

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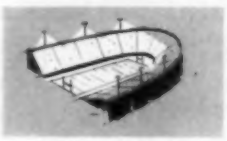

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Architect: William B. Simboli & Associates
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- Only 5½" deep for ideal ballast operation and convenient relamping.
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Sylvania's Troffer Series enjoys tremendous popularity for two basic reasons: (1) outstanding product design together with practical, time-saving features; and (2) an extremely wide range of models to fit all modern ceilings and to suit every individual taste.

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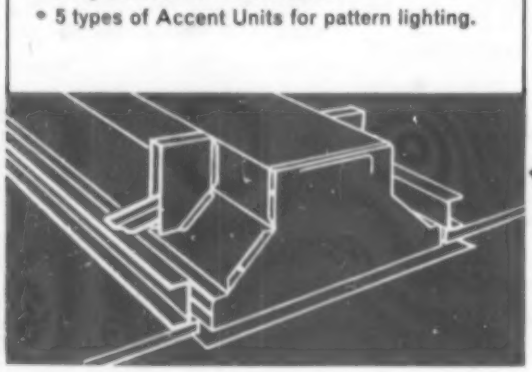

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(Continued from page 10A)

per cent, while engineering enrollment declined 7.2 per cent. In 1956-57, engineering accounted for 61.8 per cent of the total enrollment; in 1959-60, only 54.8 per cent. The physical sciences (physics, chemistry and mathematics), on the other hand, showed a 35 per cent increase over the four years and other sciences increased 16 per cent.

Thus, gains in science absorbed not only the equivalent of the losses in engineering, but three quarters of the net gain in the institution's enrollment.

While generalizations from a single example are not in order, *Manpower* states, the statistics do raise a question as to the extent to which the increasing emphasis on science in the engineering curriculum is promoting and accelerating the downward trend in engineering enrollments.

Engineer's Earning Power Studied by EMC

Approximately 200,000 engineers employed in industry, government and education will be covered by the Engineering Manpower Commission's fourth survey of earnings of engineering graduates. The study, now underway, is expected to represent the most comprehensive data published on this subject.

The last survey, conducted in 1958, showed an average increase in earnings of 6.5 per cent annually from 1953 to 1958.

The phase of the survey concerning analyzation of data received from engineering teachers will be undertaken in conjunction with the American Society for Engineering Education.

Printed reports should be available at the end of the year.

Lighting Seen as Creative Art In "My Fair Lady" Case

Recognition of a lighting design as a creative contribution was implicit in a decision by the American Arbitration Association in favor of Abe Feder, New York lighting consultant, over the use of his stage lighting design in the London production of "My Fair Lady." Mr. Feder, who designed the lighting for the New York and United States road company productions of the hit musical, was awarded $500 for his claim that H. M. Tennent, Ltd., producers of the London version of the show, violated a contractual agreement.

The arbitrators decided that the evidence in the case made "clear that in modern theatrical production, the function of the lighting designer is not merely to produce by electrical devices the general effect envisaged by the script,

(Continued on page 16A)

SCHEDULED EVENTS

August 8-12, 1960—American Institute of Electrical Engineers, Pacific General Meeting, El Cortez Hotel, San Diego, Calif.

August 22-24, 1960—National Association of Lighting Maintenance Contractors, Annual Convention, Milwaukee Inn, Milwaukee, Wis. All meetings are open to public.

September 6-16, 1960—Production Engineering Show, Navy Pier, Chicago, Ill.

September 10-18, 1960—Electrical Living Show, New York Coliseum, New York, N. Y.

September 11-16, 1960—Illuminating Engineering Society, National Technical Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

September 21-23, 1960—American Society of Mechanical Engineers—American Institute of Electrical Engineers, Power Conference, Bellevue-Stratford, Philadelphia, Pa.

September 28-30, 1960—Canadian Electrical Manufacturers Association, Sheraton-Brock Hotel, Niagara Falls, Ont.

October, 1960—American Society for Engineering Education, Annual Meeting of North-Midwest Section, Marquette University, Milwaukee, Wis.

October 5-7, 1960—International Association of Electrical Leagues, Annual Meeting, President Hotel, Kansas City, Mo.

October 9-14, 1960—American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 13-15, 1960—Optical Society of America Meeting, Somerset Hotel, Boston, Mass.

October 15-20, 1960—American Institute of Electrical Engineers, Fall General Meeting, Detroit, Mich.

October 16-18, 1960—United States National Committee, CIE, Annual Meeting, State College, Pa.

October 16-22, 1960—Society of Motion Picture and Television Engineers, Semi-Annual Convention, Sheraton Park Hotel, Washington, D. C.

October 19, 1960—Society of Plastics Engineers, Tooling for the Plastics Industry, New York, N. Y.

October 23-27, 1960—National Electrical Contractors Association, Las Vegas, Nevada.

October 25-27, 1960—American Standards Association, National Conference on Standards, Sheraton-Atlantic Hotel, New York, N. Y.

November 14-18, 1960—National Electrical Manufacturers Association (Annual Meeting), Traymore Hotel, Atlantic City, N. J.

November 17-19, 1960—Canadian Electrical Association, Engineering Sections, Western Zone, Saskatchewan Hotel, Regina, Sask.

November 21-23, 1960—Canadian Electrical Association, General and Sales Sections, Western Zone, Palliser Hotel, Calgary, Alta.

November 27-December 2, 1960—American Society of Mechanical Engineers, Annual Meeting, Statler-Hilton Hotel, New York, N. Y.

November 29, 1960—American Institute of Consulting Engineers, Annual Dinner, Waldorf-Astoria Hotel, New York, N. Y.

December 5-9, 1960—National Conference on Application of Electrical Insulation, Conrad Hilton Hotel, Chicago, Ill.

January 24-27, 1961—Society of Plastics Engineers, Inc., 17th Annual Technical Conference, Shoreham and Park Sheraton Hotels, Washington, D. C.

January 30-February 2, 1961—Plant Maintenance and Engineering Show, International Ampitheatre, Chicago, Ill.

February 13-16, 1961—American Society of Heating, Refrigerating and Air Conditioning Engineers, Semi-Annual Meeting, Conrad Hilton Hotel, Chicago, Ill.

February 26-March 1, 1961—American Institute of Chemical Engineers, National Meeting, Roosevelt Hotel, New Orleans, La.

March 2-4, 1961—Optical Society of America, Roosevelt Hotel, Pittsburgh, Pa.

April 4-6, 1961—St. Louis Board of Trade, Progress in Electrical-Electronic Equipment Exhibit, Exposition Hall, St. Louis, Mo.

April 5-7, 1961—American Institute of Electrical Engineers, Southeast Meeting, New Orleans, La.

I. E. S. National Technical Conferences

1960—September 11-16—Penn Sheraton Hotel, Pittsburgh, Pennsylvania

1961—September 24-29—Chase Park Plaza Hotel, St. Louis, Missouri

1962—September 9-14—Statler-Hilton Hotel, Dallas, Texas

1963—September 8-13—Sheraton-Cadillac Hotel, Detroit, Michigan

1964—August 30-September 3—Fontainbleau Hotel, Miami Beach, Florida

(*Continued from page* 15A)

e.g., a bright afternoon or misty morning. He plays a more significant creative part. . . . We do not doubt that Mr. Feder made substantial contributions of this order to the original production, solving some lighting problems that presented special difficulty and achieving visual results that were acclaimed."

Cornerstone Set At United Engineering Center

The Honorable Robert F. Wagner, Jr., Mayor of the City of New York, and former President Herbert Hoover were principal participants in the cornerstone setting ceremony at the United Engineering Center in New York City on June 16. Mayor Wagner, delivering the principal address at the ceremonies, expressed the pride of New York City in being chosen as the home of the 18 professional societies, including IES, which will occupy the new building.

Mr. Hoover's "Message for Posterity," was sealed in the cornerstone vault, to be opened in 100 years, together with documents from each of the societies represented in the building. The IES contribution to the cornerstone vault contained the 1959 Annual Meeting Reports by President George J. Taylor, Vice-President J. B. Browder and General Secretary James R. Chambers, bound between the covers of IE and sealed in a plastic binder.

Representing IES at the ceremonies were President and Mrs. J. B. Browder, Past President and Mrs. George J. Taylor, President-Elect R. G. Slauer, General Secretary G. F. Dean, Directors J. D. Mitchell and Joe Thomas, J. Carl Wilson and Managing Director A. D. Hinckley.

The United Engineering Center, located opposite United Nations Plaza, is scheduled for completion in the middle of 1961.

Spectroradiometer for Fluorescent Lamps Developed by NBS

A spectroradiometer to calibrate fluorescent lamp color standards has been designed by H. K. Hammond, W. L. Holford and M. L. Kuder of the National Board of Standards.

With this instrument, spectral irradiance data for a fluorescent test lamp are obtained relative to an incandescent lamp of known color temperature. These data assist in determining the exact color of the test lamp, enabling its use as a color standard throughout the industry.

Obituary

Eugene W. Commery, well-known residential lighting expert and a Fellow of IES, died in his sleep on May 25, in Allendale, South Carolina, while en route to his home in Key Biscayne, Florida. He was 66. Mr. Commery was returning from a visit to Cleveland and attendance at the IES Great Lakes Regional Conference, May 16 and 17.

His entire lighting career, following his graduation from the Case Institute of Technology in 1916, was spent with the General Electric Lamp Division. He retired from the company in October, 1958, as supervisor of residential lighting.

Eugene W. Commery

Among the most notable home lighting designs credited to Mr. Commery were the "Celestial Room" exhibited at the San Francisco Museum of Art in 1956 and the Ronald Reagan home in California. His early lighting application career was highlighted by designs for Temple Emanuel in New York City, Grand Caverns at Grottoes, Virginia, and N.B.C.'s famed "Studio H" in New York City.

His publications, in addition to numerous papers in ILLUMINATING ENGINEERING and the *Transactions of the IES*, include *How to Decorate and Light Your Home*, co-authored with C. Eugene Stephenson, and "See Your Home in a New Light," one of the most widely-circulated booklets on home lighting.

When Mr. Commery joined IES in 1922, he began a long and notable career in the Society which culminated in his election to Fellow grade in 1950 and the award of a "Citation of Achievement" at the Society's National Technical Conference in Toronto in 1958.

His IES activities included 20 years of membership on the Residence Lighting Committee with several terms as Chairman, Chairmanship of the Television Committee from 1950-1952, membership on the Color and Illumination Committee, Committee on Portable Lamp Specifications and IES representative to the Inter-Society Color Council.

He was a representative to the United States National Committee of CIE, influential in the formation of the Better-Light-Better-Sight Bureau and technical advisor to the Certified Lamp Manufacturers' Program for the promotion of better floor and table lamps for use in the home.

Following his retirement to Florida in 1958, Mr. Commery remained active as a speaker and lighting consultant. He was several times a speaker at the Southeast Florida Section and guest speaker

(*Continued on page* 21A)

READY to set the cornerstone of the United Engineering Center, New York City, are, l. to r., Andrew Fletcher, President, United Engineering Trustees, owners of the building; former President Herbert Hoover and Robert F. Wagner, Jr., Mayor of the City of New York. The ceremonies took place on June 16, eight months after the ground breaking for the building which is to house 18 engineering societies. Scheduled completion date for the UEC is mid-1961.

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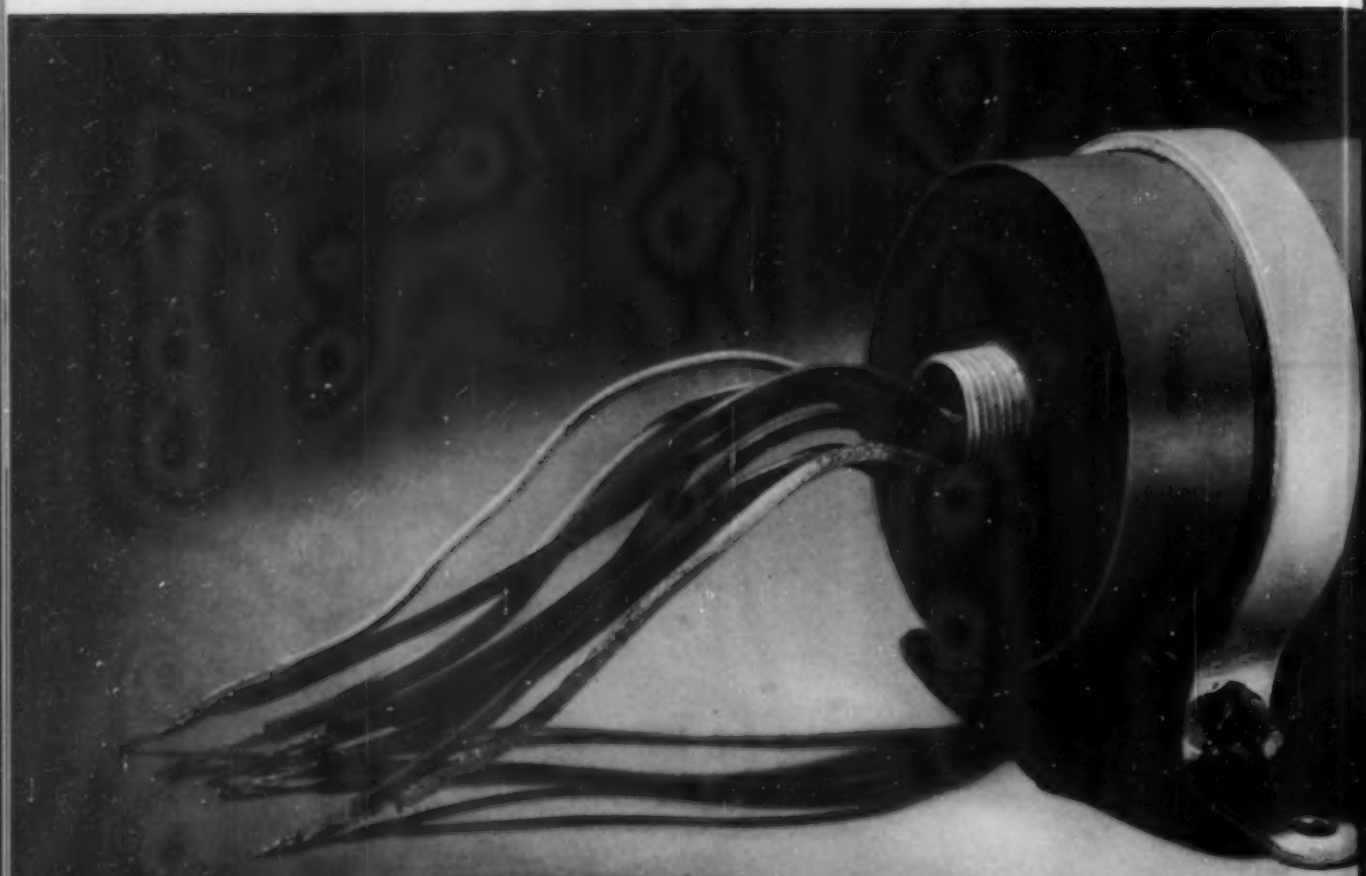
SHOVELITE

REC-54

The REC-54 utilizes the Rambusch Shovel® Reflector to wash walls with light. It illuminates paintings, displays or wall murals as shown in the illustration. The aperture is small (only 3⅜ inches in diameter) but the unit can be serviced from below. Naturally, there is no exposed hardware, the face plate is flush with the ceiling, and the device utilizes a standard 100 or 150 watt lamp. Write for detailed data sheet DL-15 or see Sweet's Catalog—Lighting 33a/Ra

ANOTHER EXAMPLE OF GENERAL ELECTRIC

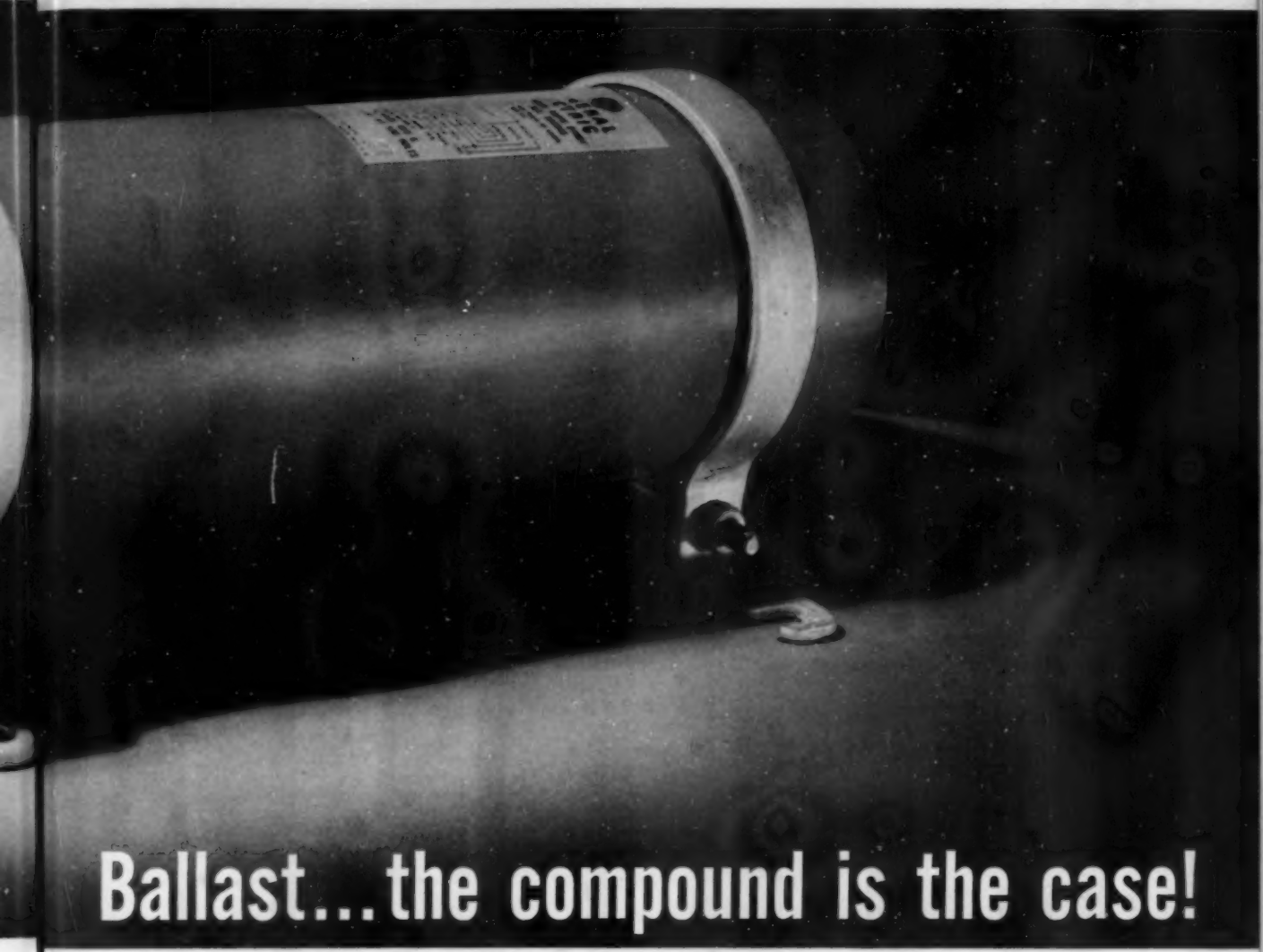


NEW General Electric Weatherproof

GORDON C. HARVEY, Manager of Engineering, General Electric Ballast Department, explains the significance of this important new fluorescent lamp ballast development.

"Take a good look at the NEW shape in ballast design above. You'll be seeing and hearing a lot about it during the next few months.

BALLAST ENGINEERING LEADERSHIP . . .



Ballast...the compound is the case!

"General Electric Company, which introduced the first weatherproof ballast in 1955, has developed an entirely new weatherproof ballast that can be installed in any position. Movable brackets and your choice of junction boxes make it easy for you to mount the new General Electric weatherproof ballast *anywhere*—without danger of water damage.

"Progress like this doesn't just happen. It is the result of experience gained since General Electric introduced the first fluorescent lamp ballast back in 1939. It is a product of diligent searching and testing in General Electric research laboratories, the most complete and widely respected in the industry. It comes from knowing what *you* want and being able to deliver when you need it."

Proved product excellence and engineering leadership are important reasons why you should always insist on General Electric ballasts for all your fluorescent lighting applications. For more information, write Section 401-72, General Electric Co., Danville, Illinois.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Since 1946
the City of Chicago
has installed...

141,800

UNION METAL STREET LIGHTING POLES

Experience, acceptance, attractive design—these are the reasons why Union Metal is first in lighting pole sales throughout the nation.

Monotube Lighting Poles

UNION METAL

The Union Metal Manufacturing Co.

Canton 5, Ohio • Brampton, Ontario, Canada

MARKING the close of the Panhandle Chapter's 1959-1960 year, Tom Lynn (left), chairman of the board of governors, presents a certificate of appreciation to retiring chairman Gordon Baldry (center) and an honorary membership to C. B. Marsh, Sr., an IES member for over 30 years. C. B. Marsh, Jr. (right), accepted for his father who was unable to attend the meeting due to illness.

(Continued from page 16A)

at the first meeting of the Ft. Lauderdale Study Club. In addition, he was awarded honorary membership in the American Institute of Decorators and served as a member of the board of directors of the regional AID.

ABOUT PEOPLE

Alfred Bersted has been elected president of the McGraw Edison Co., succeeding **Max McGraw,** founder of the company, who had held the position for 60 years. Mr. McGraw has become chairman of the company's newly-formed executive committee, a seven-man group composed of himself, the president, executive vice-president, secretary, one operating division director and two non-operating division directors, the latter to change semi-annually.

In connection with the recent acquisition of a Manchester, N. H. plant for the manufacture of mercury-vapor lamps and associated products, Sylvania Lighting Products has announced two new appointments. **Daniel S. Gustin** who had been in charge of engineering on mercury, glass tube, PAR and projection lamps since 1959, will be engineer-in-charge at the new plant. **Michael Balog,** the new plant manager, was associated with Sylvania in various capacities from 1941 to 1959, and recently rejoined the company after a year as manager of the CBS electronic radio tube plant.

In another Sylvania announcement, **L. John Doyle** was named to the position of field sales manager, large lamp products, with responsibility for all field sales activities, national accounts and sales management development. Mr. Doyle joined the company as a field representative in Los Angeles, and for the past eight years has been district sales manager in the Detroit area. As field sales manager, he will have his office at the Lighting Division headquarters in Salem, Mass.

Robert H. Shaffer has been appointed vice president in charge of manufacturing for Pacific Associated Lighting, Inc., with responsibility for the management of PALCO's newly constructed San Francisco plant.

The Board of Directors of Major Equipment Co., Chicago, Ill. has announced the election of **Robert A. Major** as vice president. In addition to his responsibilities in this position, Mr. Major will continue to supervise sales in the company's Alzak Division.

The promotion of **Charles W. Hargens** to the position of technical director in charge of electrical engineering has been announced by **Dr. Nicol H. Smith,** Laboratories Director of the Franklin Institute, Philadelphia. Mr. Hargens, who has been head of the Laboratories Bioelectronics branch since 1958, will direct all research and development programs in the fields of electronics, life sciences instrumentation (bioelectronics), electromechanics and power and control systems.

Eve Freyer has resigned as residential lighting consultant, Westinghouse Lamp Division, Bloomfield, N. J., to join the Station Apparatus Development Department, Bell Telephone Laboratories, Murray Hill, N. J., in an engineering position. Prior to joining Westinghouse, in January, 1955, Miss Freyer served, for six years, as engineering assistant to IES Technical Director, C. L. Crouch.

Clarence W. Clarkson has been appointed lighting glassware sales representative for the Eastern Sales District, Corning Glass Works. In this position, he will work directly with architects and engineers in the New York City area from his headquarters at Corning's New York offices. Associated with Corning since 1944, Mr. Clarkson has served as a lighting engineer, sales engineer, product specialist and applications engineer for the lighting sales department.

Prescolite Mfg. Corp., has named **Pete Wyman** as sales representative for the San Francisco area, with headquarters at the company's home offices in Berkeley, Calif. Mr. Wyman joined Prescolite last February after having been associated with Silvray Lighting, Inc., Curtis Lighting, Inc., Pittsburgh Reflector Co. and Paul F. Kyack, Inc.

Norman Pattee has announced the establishment of a lighting manufacturers' representative agency, Lighting Center, in Kansas City, Mo. Mr. Pattee was previously associated with the General Electric Supply Co. and, most recently, wtih the W. T. Foley Electric Supply Co., Kansas City.

The **Charles D. White** Co., Boston, Mass., will represent the Dynaray Lighting Equipment Division of Electro Powerpacs, Inc., Cambridge, Mass., in all of New England with the exception of Connecticut.

Western Lighting Corp., Los Angeles, Calif., has announced the appointment of **Don Glass** as a sales engineer. Mr. Glass was associated with Graybar Electric Co. for many years and, more recently, with a large manufacturer of lighting products.

Thomas R. Skidmore is the new product specialist for the Hubbard Aluminum Products Division of Hubbard & Co. Working out of the Division's headquarters in Pittsburgh, he will be re-

(Continued on page 22A)

(Continued from page 21A)

sponsible for field sales organization contact. Mr. Skidmore has a sales background in traffic control equipment, overhead sign structures and aluminum lighting standards.

Frank J. Bernd and **Charles T. Wallace** have joined the firm of C. B. Thorsen and Associates, Chicago representatives for Day-Brite Lighting, Inc. Both men were previously associated with Curtis-AllBrite Lighting, Inc., Mr. Bernd as general manager and Mr. Wallace as general sales manager of the Curtis Lighting Division of the company.

Leland Ohio Electric Co., Dayton, Ohio, has appointed **G. William Schreck** to the position of sales manager. Mr. Schreck has been connected with Leland since 1950, serving as Cleveland regional manager since 1954.

Professor **Antoine Marc Gaudin** of the Massachusetts Institute of Technology has been elected chairman of the Engineering Foundation, a United Engineering Trustees department "for the furtherance of research in science and engineering and the advancement in any other manner of the profession of engineering and the good of mankind." He succeeds **W. M. Peirce** of New York. Others elected to Foundation posts include: Vice-Chairman, **George O. Crume, Jr.,** Union Carbide Corp.; Director, **H. K. Work,** New York University; Member, Executive Committee, **Carl W. Borgmann,** Ford Foundation; Board Members, **Augustus B. Kinzel,** Union Carbide Corp., **John H. Hitchcock,** Morgan Construction Corp.

At the annual meeting of the American Institute of Electrical Engineers on June 20 in Atlantic City, N. J., the election of **Clarence H. Linder,** General Electric Co., New York, as AIEE president for 1960-1961 was announced. Elected as AIEE vice presidents were: **C. E. Gaylord,** New York Telephone Co., Buffalo, N. Y.; **R. T. Weil, Jr.,** Manhattan College, New York City; **F. W. Bush,** Allis Chalmers Mfg. Co., Milwaukee, Wis., **S. C. Wright,** Southwestern Bell Telephone Co., Oklahoma City, Okla.; **H. A. Carlberg,** General Electric Co., Richland, Wash.; **A. W. Rauth,** Consumers Power Co., Jackson, Mich.; **Walter Criley,** Vanderbilt University, Nashville, Tenn. and **P. G. Wallace,** Texas Power & Light Co., Dallas, Texas.

Deaths

A. V. Hutchinson, Lafayette, Ind.
Richard W. Spry, New England Section.

IES Officers, 1960-1961

At the meeting of the IES Council on June 16, 1960, the Committee of Tellers presented their report on the results of the recent Society election. The following have been elected to the offices indicated, for the year beginning October 1, 1960.

GENERAL OFFICERS

President—Richard G. Slauer, Sylvania Electric Products, Inc., Wheeling, W. Va.
Vice-President—G. F. Dean, Toronto Hydro-Electric System, Toronto, Ont.
General Secretary—J. D. Mitchell, Westinghouse Lamp Division, Chamblee, Ga.
Treasurer—W. P. Lowell, Jr., Sylvania Electric Products, Inc., Salem, Mass.
Directors (Until 1963)—A. C. Barr, General Electric Co., Nela Park, Cleveland, Ohio; R. L. Smart, Boston Edison Co., Boston, Mass.
Regional Vice-President—Great Lakes Region—Alston Rodgers, General Electric Co., Nela Park, Cleveland, Ohio; *Midwestern Region*—R. D. Cohen, Glasco Electric Co., St. Louis, Mo.; *North Central Region*—R. M. Smart, Sylvania Electric Products Inc., Melrose Park, Ill.; *Northeastern Region*—Robert L. Zahour, Westinghouse Electric Corp., Bloomfield, N. J.; *Pacific Northwest Region*—J. T. Cottingham, Portland General Electric Co., Portland, Ore.; *South Central Region*—J. S. Williams, Arkansas Power & Light Co., Little Rock, Ark.; *South Pacific Coast Region*—R. H. Kreyser, Dept. of Water & Power, City of Los Angeles, Calif.

ALABAMA SECTION

Chairman—R. P. Fulmer, Westinghouse Electric Corp., 1407 Comer Bldg., Birmingham, Ala.
Vice-Chairman—R. D. Steele, Alabama Power Co., Birmingham, Ala.
Secretary—Pat Krahenbuhl, Canterbury Electric Co., 1013 7th Ave. S., Birmingham, Ala.
Board of Managers—F. H. Britton, Jr., Roger Frank, D. G. Hallmark, M. B. Hazzard.

ALAMO SECTION

Chairman—Hugh Acock, Nu Ro Co., Box 8187, San Antonio, Texas.
Vice-Chairman—L. W. Travis, Beretta, Greenslade & Associates, Inc., San Antonio, Texas.
Secretary—W. S. Smith, Square D Co., 519 Travis Bldg., San Antonio, Texas.
Board of Managers—K. L. Cotton, F. A. Covington, Sr., G. L. Kocian, Jr., M. E. Staley.

ARIZONA SECTION

Chairman—S. S. Lambe, Salt River Project, P.O. Box 1980, Phoenix, Ariz.
Vice-Chairman—William Benndorf, William Benndorf Co., Phoenix, Ariz.
Secretary—D. L. Ruff, Arizona Public Service Co., P.O. Box 2591, Phoenix, Ariz.
Board of Managers—J. B. Bennan, R. W. Godemann, J. D. Whitnell, J. R. Williams.

BRITISH COLUMBIA SECTION

Chairman—J. E. Baker, 2193 Argyle Ave., West Vancouver, B. C.
Vice-Chairman—D. E. Holland, M. A. Thomas, P.E., Vancouver, B. C.
Secretary—G. F. Buzan, 2761 West Third Ave., Vancouver, B. C.
Board of Managers—E. E. Ackland, H. B. Bradley, C. R. Coldwell, William MacDonald.

CAPITAL SECTION

Chairman—K. W. Cobb, 2430 Pennsylvania Ave. N.W., Washington, D. C.
Vice-Chairman—C. E. O'Daniel, Potomac Electric Power Co., Washington, D. C.
Secretary—N. H. Boehm, General Electric Co., 777 14th St., N.W., Washington, D. C.
Board of Managers—E. F. Bailer, T. F. Coghlan, A. A. Fox, N. G. Malcomian.

CENTRAL NEW YORK SECTION

Chairman—R. C. Swanson, Jr., Niagara Mohawk Power Corp., 300 Erie Blvd. W., Syracuse, N. Y.
Vice-Chairman—D. R. Brown, Crouse-Hinds Co., Syracuse, N. Y.
Secretary—W. F. Crosby, Jr., Corning Glass Works, Corning, N. Y.
Board of Managers—J. F. Buckley, Robert Caryl, J. A. Lacy, V. J. Moore.

CHICAGO SECTION

Chairman—E. H. Gallet, Advance Transformer Co., 2950 N. Western Ave., Chicago, Ill.
Vice-Chairman—E. H. Witte, Benjamin Electric Mfg. Co., Des Plaines, Ill.
Secretary—A. J. Morelli, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
Board of Managers—B. F. Avery, V. T. Kampf, J. A. Schneller, H. E. Sereika.

CLEVELAND SECTION

Chairman—W. H. Johnson, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland, Ohio.
Secretary—W. S. Fisher, Jr., General Electric Co., Nela Park, Cleveland, Ohio.
Board of Managers—C. J. Allen, J. R. Bale, W. J. Culf, T. C. Norton, L. S. Sternberg.

CONNECTICUT SECTION

Chairman—J. J. Neidhart, The Miller Co., Meriden, Conn.
Vice-Chairman—R. H. Chase, Hartford Electric Light Co., Hartford, Conn.
Secretary—C. C. Harper, 96 Robin Hill Road, Meriden, Conn.
Board of Managers—W. P. Carpenter, J. T. Dolan, J. F. McInnis, Robert Van Houten.

CORNHUSKER SECTION

Chairman—W. M. Scholes, Omaha Public Power District, Omaha, Nebr.
Vice-Chairman—E. C. Kundson, Leo A. Daly Co., Omaha, Nebr.
Secretary—Fred Engelhardt, Omaha Public Power District, Omaha, Nebr.
Board of Managers—R. W. Brewer, H. J. Palmer, J. A. Peterson, C. I. Wallin.

DIABLO SECTION

Chairman—L. A. Komer, Sylvania Electric Products Inc., 1811 Adrian Road, Burlingame, Calif.
Vice-Chairman—F. J. Bertolone, Fluorescent Fixtures of California, San Francisco, Calif.
Secretary—Hunter Lauer, Pacific Gas & Electric Co., 1625 Clay St., Oakland, Calif.
Board of Managers—R. B. Dygert, G. N. Radford, H. H. Robison, D. E. Seely.

EASTERN NEW YORK SECTION

Chairman—J. C. Gould, Niagara Mohawk Power Corp., 30 Second St., Troy, N. Y.
Vice-Chairman—R. H. Rice, Westinghouse Electric Corp., Albany, N. Y.
Secretary—C. E. Waldron, Niagara Mohawk Power Corp., 126 State St., Albany, N. Y.
Board of Managers—R. L. Cooper, R. F. Hussey.

(Continued on page 29A)

Annual Meeting

In accordance with Article VII Section 1 of the Constitution of the Illuminating Engineering Society, the Annual Meeting will be held in conjunction with the National Technical Conference in Pittsburgh. The Meeting will be held at the Opening Session of the Conference, Monday, September 12, 1960, at which time the National Officers will report to the membership.

ZZZZZ

You know this little man. His isn't just a personal problem. He's a problem to you, too.

He goes around at night as if he were sleepwalking. He pops out without caution from behind a car. He crosses, without looking, at the darkest corner.

You jam on the brakes. Then, a block later, you sweat a little, thinking of what *could* have happened.

Why didn't you see him? Blame it on the street lights!

Proper street lighting means more than hanging up enough light bulbs. If your streets and highways have aimless patterns of light and shadow, your lamps aren't doing their job.

Corning makes glass refractors that *control* light distribution from street lamps. These refractors eliminate wasted light. They direct light where it's needed to help a whole city drive and walk with greater safety.

The resistance of PYREX® refractors to thermal and mechanical shock, their ability to take higher wattages, are some of the reasons why most major manufacturers of street lighting equipment have PYREX lenses in their line.

Another reason is Corning's capability for designing lenses to meet the most difficult optical specifications.

For information, just write Corning Glass Works, 61 Crystal Street, Corning, New York.

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS

{OOOH look at that mess!

. . . and it's so unnecessary
since Jefferson announced

DRI-LOK

the ballast
that can't
drip compound

Gone forever is the danger of messy compound leakage. In the new Jefferson DRI-LOK ballast, conventional compound has been replaced by a newly developed thermo-setting material. This dry, solid-fill material is so physically and chemically stable it cannot soften or liquefy, cannot combine or react with any other material in the ballast. It fills the *entire* case and *permanently* bonds case, core and coil into one solid, voidless unit.

The New DRI-LOK Ballast is Engineered to Meet Newly Proposed CBM Higher Light Output Standards

Write today for complete details and specifications.

NOW IN PRODUCTION

Jefferson DRI-LOK

New Blue FLUORESCENT BALLASTS

JEFFERSON ELECTRIC COMPANY • BELLWOOD, ILLINOIS

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of the

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1860 Broadway, New York 23, N. Y.

The Publications of the Illuminating Engineering Society listed here summarize the vast amount of research, investigation and discussion of hundreds of qualified members of the Society working on technical committees, and carry the full approval and authority of the Illuminating Engineering Society.

I.E.S. Publications are available, in single copies as priced, to anyone requiring knowledge of the newest in lighting application and the supporting technical information. Should quantities be desired for further distribution, such as for educational or promotional purposes, prices may be obtained by writing Publications Office.

This is your order form. Indicate number of copies ordered before each item; fill in name and address on back of form.

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NEWEST of famous I.E.S. Lighting Handbooks. Published March 1959. Over 1100 pages latest information on lighting techniques, applications and theory . . . plus equipment data. Includes all new lighting levels developed from Blackwell research studies. All-new index and cross-index. Application sections rearranged for subject headings; 25 sections in all, many new. Complete revision of previous two editions; more comprehensive, easier to use than ever.

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These booklets are the complete, standard recommendations for lighting the prescribed areas, and are among the most comprehensive and important of all Society publications. As indicated, some of these recommendations are the work of committees of the American Standards Association, with collaboration by appropriate committees of the I.E.S. All have the approval of the Council of the Illuminating Engineering Society, and the the latest official I.E.S. recommendations.

In general, the information contained in these Recommended Lighting Practices covers completely the area shown in the title. Included in the data are suggested types of lighting systems and luminaires; levels for general lighting and for specific areas; analyses of seeing tasks; and other information essential to lighting the area and of value to lighting engineers and specialists, architects, construction people and others. Each practice is fully illustrated with charts and photographs.

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I.E.S. Recommended Practice 36 pp. 50c

— **RP-4 LIBRARY LIGHTING (1950)**
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— **RP-5 DAYLIGHTING (1950)**
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— **RP-7 INDUSTRIAL LIGHTING (1952)**
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— **RP-8 STREET AND HIGHWAY LIGHTING (1953)**
American Standard Practice 32 pp. 50c

— **RP-9 SUPPLEMENTARY LIGHTING (1953)**
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— **RP-10 PROTECTIVE LIGHTING (1956)**
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RP-2 (Stores & Other Merchandising Areas), RP-3 (School Lighting) and RP-6 (Sports Lighting) are out of print. When revised publications are available they will again appear on this list.

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Lighting recommendations based upon studies (research, surveys of current practice, and experimental installations) of I.E.S. Committees and Subcommittees covering all phases of lighting. Completely illustrated, these reports contain detailed information on many lighting problems peculiar to the industry or operation involved as well as providing general data as to lighting systems and luminaires; recommended quantity and quality of illumination; and analyses of specific seeing tasks.

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— **CP-5 LIGHTING FOR BAKERIES** 16 pp. 50c

— **CP-6 LIGHTING OF CENTRAL STATION PROPERTIES, CONTROL AND LOAD DISPATCH ROOMS** 20 pp. 50c

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— **CP-9 LIGHTING INDOOR LOCATIONS OF CENTRAL STATION PROPERTIES** 20 pp. 40c

— **CP-10 LIGHTING FOR STEEL MILLS PART I: OPEN HEARTH** 8 pp. 50c

— **CP-11 LIGHTING FOR FOUNDRIES** 16 pp. 50c

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— **CP-15 FUNCTIONAL VISUAL ACTIVITIES IN THE HOME** 12 pp. 25c
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— **CP-17 PROGRESS IN TELEVISION STUDIO LIGHTING Addenda to CP-16** 4 pp. 10c

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Each I.E.S. Lighting Data Sheet describes an actual, outstanding lighting installation, complete with photographs, drawings and engineering data. They are published in a series of 24 sheets each year, and current sheets cover such subjects as lighting for metalworking, textile, automobile and other industries; schools; stores; offices; drafting rooms; churches; auditoriums; banks; museums; indoor and outdoor recreational areas; streets and highways; and other special applications.

Printed on heavy gloss paper, punched for standard ring binder, data sheets are an excellent "idea" file for lighting people, consulting engineers and architects; ideal for promotional distribution by manufacturers and electric utilities.

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Many lighthouses don't deliver as much light as this *one* 8-foot Sylvania VHO Powertube. 15,000 lumens! Smooth, white, and no glare!

It's not surprising that more and more companies use Sylvania VHO (Very High Output) Powertubes in all sizes —indoors and out! Only Sylvania Powertubes give you all this:

- **2½ times more light** than you get from standard fluorescent lamps of the same size.
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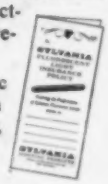
- **Slimmer size.** T-12 1½" tube diameter means better air circulation around tube than larger diameter lamps.
- **Uniform light distribution.** Sylvania VHO Powertubes deliver full light output in any position.
- **Better optical control.** You get full use of light because it can be *directed* exactly where you want.
- **Lowest TCL—total cost of lighting**—means lowest cost of lamp plus power plus maintenance.
- **Exclusive Light Insurance Policy.** Sylvania lamps are *guaranteed* to perform better in your opinion than the brand you are now using . . . or your money back!

EXTRA! INSTALLATION SERVICE. Sylvania engineers have also developed a more effective mounting system *and* directional control for fluorescent lamps. Called CFR (Controlled Fluorescent Reflectance), it brings greater efficiency, light reflectance from VHO Powertubes. Ask your Sylvania representative. Call him, or write us:

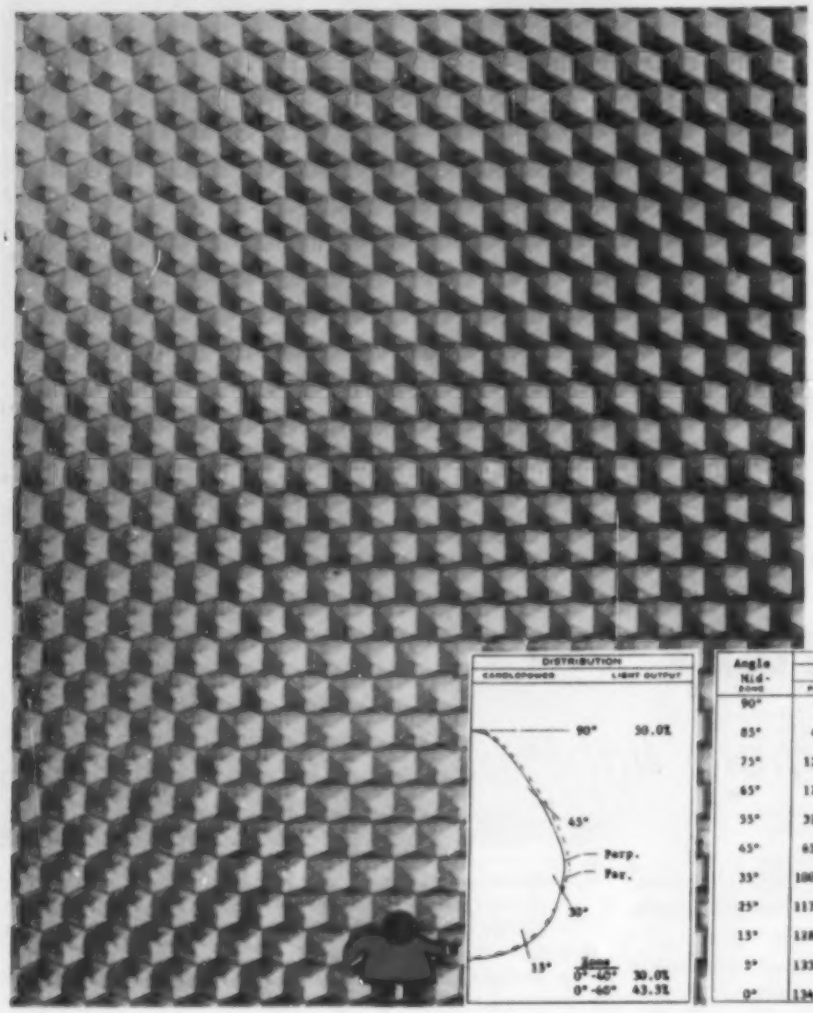


Sylvania Lighting Products, a Division of Sylvania Electric Products Inc., Dept. 61, 60 Boston Street, Salem, Mass. In Canada: Sylvania Electric (Canada) Ltd., P.O. Box 1190, Station "O," Montreal 9

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

announcing the New EXTRU-LITE® Pattern R-7

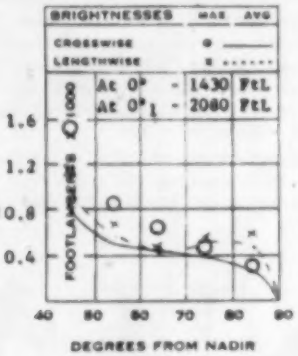


our famous plastic low brightness lensware — NOW extruded in a Brand NEW PATTERN.

Pattern R-7, with optically engineered hexagonal pyramids, permits the light to enter at all angles from the light source. It diffuses and refracts the light onto the work surface with a low brightness that is highly desirable for all types of visual tasks.

This 6-sided prismatic pattern controls, directs and reflects the rays to provide a glareless, more uniform light distribution.

Angle Mid-Zone	Mid-Zone Candlepower — Horizontal Angles					Lumens
	Par.	Zone	45	Zone	Perp.	
90°	0		0		0	-
85°	40.2		40.2		25.3	40
75°	127		125		96.9	125
65°	176		200		179	188
55°	317		313		279	274
45°	633		620		354	672
35°	1883		1900		970	625
25°	1177		1198		1196	551
15°	1281		1293		1301	363
5°	1334		1335		1338	127
0°	1341		1341		1341	-



Made of plastic in either polystyrene or acrylic, it has all the advantages of plastic; such as, light weight (approximately .55 lbs. per sq. ft.); therefore easier to handle. It is tougher, more durable and safer.
Also more economical to maintain.

Extruded up to 24" wide in 1/8" or 3/16" thicknesses. Either crystal clear or by special request in varying degrees of opal white translucence.

Write or call our factory or our Sales Offices today for Free Samples, Brochure and Price List.

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(*Continued from page 22A*)

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Chairman—R. C. Hamsher, Pennsylvania Power & Light Co., 9th & Hamilton Sts., Allentown, Pa.
Vice-Chairman—J. H. Bicher, General Electric Corp., Reading, Pa.
Secretary—R. J. Mott, Electro-Silv-A-King Corp., Spruce & Water Sts., Reading, Pa.
Board of Managers—Rudolph Kerchmar, Roy McCarter, C. H. Steigerwalt, Jr., Neal Trullson.

EDMONTON SECTION

Chairman—H. E. Mather, Alberta Electrical Supplies Ltd., 10168-106th St., Edmonton, Alta.
Secretary—W. R. Vernon, 10357-109th St., Edmonton, Alta.
Board of Managers—E. B. Allsopp, J. B. Bradshaw, J. G. Forbes, A. T. Robertson, Roger Young.

FLORIDA SECTION

Chairman—B. P. Best, 1450 Coral Way, S., St. Petersburg, Fla.
Vice-Chairman—R. R. Minton, Bishop & Johnson, Inc., Tampa, Fla.
Secretary—D. A. Whitston, Florida Power Corp., 908 Cleveland St., Clearwater, Fla.
Board of Managers—D. J. Faulkner, H. G. Hayes, J. A. Pettus, R. L. Sirmons.

GEORGIA SECTION

Chairman—J. J. Burns, General Electric Co., 361 E. Paces Ferry Rd. N.E., Atlanta, Ga.
Vice-Chairman—L. R. Bush, 36 Peachtree Pl. N.W., Atlanta, Ga.
Secretary—W. T. Cantrell, Georgia Power Co., 15 Forsyth St. S.W., Atlanta, Ga.
Board of Managers—S. J. Andre, R. L. Carmichael, A. N. Lundstrom, J. T. Pyron, Jr.

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Chairman—F. E. Duhme, Jr., Smoot Holman Co., 55 Mississippi St., San Francisco, Calif.
Vice-Chairman—A. S. Tylor, 1037 Cortez Ave., Burlingame, Calif.
Secretary—R. L. Sawyier, Jr., Pacific Gas & Electric Co., Oakland, Calif.
Board of Managers—W. G. Bayha, J. H. Burson, J. C. Epperson, C. W. Macy.

HEART OF AMERICA SECTION

Chairman—Charles Purcell, 615 West 70th St., Kansas City, Mo.
Secretary—G. V. Dawson, Jr., Glasco Electric Co., 919 E. 19th St., Kansas City, Mo.
Board of Managers—J. R. Custead, J. D. Hilburn, Jr., T. B. Smith, E. P. Stone, R. W. Wilson.

INDIANA SECTION

Chairman—H. W. Claffey, Jr., General Electric Co., 3333 N. Meriden St., Indianapolis, Ind.
Vice-Chairman—N. F. Schnitker, Indianapolis Power & Light Co., Indianapolis, Ind.
Secretary—M. B. Wolfe, 3955 Riley Ave., Terre Haute, Ind.
Board of Managers—Cecil Adams, A. S. Coffin, Jr., L. W. Miles, N. J. Reinhart.

IOWA SECTION

Chairman—L. J. Kingsley, Crescent Electric Supply Co., 313 S.W. 5th St., Des Moines, Ia.
Vice-Chairman—Arne Oja, George C. Mittauer & Associates, Cedar Rapids, Ia.
Secretary—J. Z. Maffitt, Iowa Power & Light Co., 823 Walnut, Des Moines, Ia.
Board of Managers—Leonard DeHoet, E. H. Ford, R. F. Gruhl, Mary E. Stafford.

MARYLAND SECTION

Chairman—Richard Dunlop, Dunlop Lighting, 12-14 E. 24th St., Baltimore, Md.
Vice-Chairman—S. E. Ehrlich, Excello Public Service Corp., Baltimore, Md.
Secretary—J. C. Burdette, Jr., Egli & Gompf, Inc., 1003 N. Calvert St., Baltimore, Md.
Board of Managers—C. H. Bronner, R. C. Desor, M. E. Gillespie, J. D. Smith.

MIAMI VALLEY SECTION

Chairman—P. E. Wehner, R.R. #1, Byers Road, Miamisburg, Ohio.
Vice-Chairman—I. G. Holmer, Dayton Power & Light Co., Dayton, Ohio.
Secretary—S. L. Burnham, General Electric Co., 225 N. Wilkinson St., Dayton, Ohio.
Board of Managers—W. E. Blommel, B. H. Bordwell, E. A. Hart, Howard Wannemacher.

MICHIGAN SECTION

Chairman—D. J. Theisen, Sylvania Electric Products Inc., 7800 Intervale, Detroit, Mich.
Secretary—W. A. Hedrich, University of Michigan, Ann Arbor, Mich.
Board of Managers—H. F. Eckert, J. W. Fenn, S. S. Squillace, Mary B. Taepke, G. S. Thornton.

MILWAUKEE SECTION

Chairman—Edwin Schnoll, Schnoll Lighting Sales, 7632 N. Van Dyke Rd., Milwaukee, Wis.
Vice-Chairman—C. A. Knoerr, Knoerr & Fischer, Inc., Milwaukee, Wis.
Secretary—K. O. Hartwig, Graybar Electric Co., 180 N. Jefferson St., Milwaukee, Wis.
Board of Managers—R. L. Garber, L. C. Odry, R. J. Present, W. J. Schumaker.

MONTREAL SECTION

Chairman—A. J. Hanley, Paul De Guise, Consulting Engineer, 3760 Harvard, Montreal, Que.
Secretary—W. J. McCormick, Sylvania Electric (Canada) Ltd., P.O. Box 1190, Station "O," Montreal, Que.
Board of Managers—L. J. Adams, J. H. Beaudet, R. Gohier, J. R. Levins, W. G. Moore.

NEW ENGLAND SECTION

Chairman—L. A. Bean, Vorlander Lighting, 80 Boylston St., Boston, Mass.
Vice-Chairman—J. E. Carr, General Electric Co., Boston, Mass.
Secretary—P. M. Crosby, Cambridge Electric Light, 46 Blackstone, Cambridge, Mass.
Board of Managers—P. J. LePore, J. A. MacCracken, H. W. Robinson, R. B. Wylie.

NEW JERSEY SECTION

Chairman—W. S. Till, Westinghouse Electric Corp., Bloomfield, N. J.
Vice-Chairman—M. H. Silverman, Fluores-O-Lite Co., Hillside, N. J.
Secretary—R. B. Cole, Jr., Jersey Central Power & Light Co., 400 E. Main St., Denville, N. J.
Board of Managers—F. E. Infanger, Julius Kaye, H. O. Spliethoff, H. L. Sykes.

NEW ORLEANS SECTION

Chairman—G. C. Schroeder, Schroeder & Associates, 5591 Canal Blvd., New Orleans, La.
Vice-Chairman—J. A. Stelly, Gulf States Utilities Co., Baton Rouge, La.
Secretary—T. L. Hall, Halco Lighting Mfg. Co., 925 Gaiennie St., New Orleans, La.
Board of Managers—Edna P. Fortier, V. L. Goodman, L. H. Penny, Jr., A. W. Tannehill.

NEW YORK SECTION

Chairman—H. J. Peters, Consolidated Edison Co. of N. Y., 4 Irving Place, New York, N. Y.
Vice-Chairman—R. G. Williams, Century Lighting Inc., New York, N. Y.
Secretary—H. J. Wald, Wald & Zigas, 23-03 45th Rd., Long Island City, N. Y.
Board of Managers—C. S. Bramley, Norman Falk, E. O. Kassman, R. S. Wissoker.

NORTH TEXAS SECTION

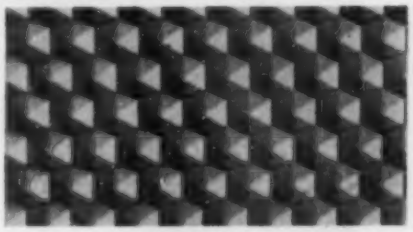
Chairman—B. L. Cook, 7106 Bennington Drive, Dallas, Texas.
Vice-Chairman—H. G. Jones, Texas Electric Service Co., Fort Worth, Texas.
Secretary—W. T. Kimery, Dallas Power & Light Co., 1506 Commerce, Dallas, Texas.
Board of Managers—P. A. Crick, A. M. Gaynor, G. D. Gill, G. H. Thaxton.

NORTHWESTERN OHIO SECTION

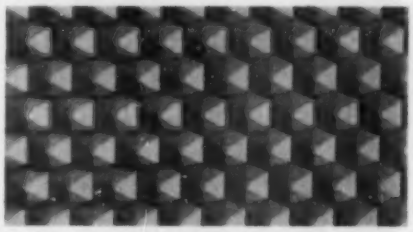
Chairman—Paul Hood, Eggleston & Son, 255 Gradolph, Toledo, Ohio.
Vice-Chairman—T. F. Wagner, Westinghouse Electric Supply Co., Toledo, Ohio.
Secretary—Audrey C. Wegener, Toledo Edison Co., Toledo, Ohio.
Board of Managers—H. E. Carney, H. B. Millar, S. E. Nagel, R. D. Rogers.

(*Continued on page 30A*)

it's amazing . . .



it's new . . .



it's all plastic.*

EXTRU-LITE'S® New Pattern R-7

has all the plus features of plastic—safety, durability, economical upkeep and light weight.

R-7 is patterned of 6-sided pyramids, optically engineered with precision correctness, to control, direct and refract rays from the fixture to produce more uniform light distribution.

The resulting low brightness creates a soothing atmosphere for greater working efficiency.

Send for FREE Sample, Brochure, Test Report & Price List.

*available in polystyrene or acrylic

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Joe E. Pearce	Indianapolis, Ind.
David B. Young	New Orleans, La.
Edward Rubin	Baltimore, Md.
Tom O'Neill	Dearborn, Mich.
Frank P. Deveny	Minneapolis, Minn.
Curt W. Carlson	Kansas City, Mo.
Fred P. Walter	St. Louis, Mo.
Harvey L. Sykes	Freehold, N. J.
Herman Robbins	White Plains, N. Y.
Centralite Co.	Cincinnati, Ohio
Irvin Spero	South Euclid, Ohio
J. W. Shively	Drexel Hill, Pa.
V. E. Hendrickson	Pittsburgh, Pa.
L. W. Roberts Co.	Richmond, Va.
George T. Howard	Seattle, Wash.
Badger Agency	Madison, Wis.

(Continued from page 29A)

OHIO VALLEY SECTION

Chairman—H. J. Gruber, Cincinnati Gas & Electric Co., 4th & Main Sts., Cincinnati, Ohio.
Vice-Chairman—J. B. Murnane, General Electric Co., Cincinnati, Ohio.
Secretary—E. J. McGinnis, Cincinnati Electrical Association, 1107 Union Trust Bldg., Cincinnati, Ohio.
Board of Managers—R. L. Campbell, A. J. Fischer, J. J. Steenken, R. G. Wilfert.

OIL CAPITAL SECTION

Chairman—J. R. Seay, Seay Electric Co., 423 W. Third, Tulsa, Okla.
Vice-Chairman—J. C. Penafeather, 745 S. 90th East Ave., Tulsa, Okla.
Secretary—W. J. Klaus, Crouse-Hinds Co., 820 E. 6th St., Tulsa, Okla.
Board of Managers—R. Almond, J. C. Netherton, Jr., W. T. Walters, F. A. Whiteside.

OREGON SECTION

Chairman—F. A. Farley, Benjamin Electric Mfg. Co., 4725 S.W. 18th Pl., Portland, Ore.
Vice-Chairman—Jitsuo Yoneyama, Corps of Engineers, Portland, Ore.
Secretary—Al Natalie, Pacific Power & Light Co., 920 S.W. 6th, Portland, Ore.
Board of Managers—L. L. Garrison, J. A. Schuiter, O. A. Taylor, R. S. Wickham.

OTTAWA SECTION

Chairman—S. D. McGann, Dept. of National Defense, Cartier Square, Ottawa, Ont.
Vice-Chairman—S. A. Dawson, Amalgamated Electric Corp. Ltd., Ottawa, Ont.
Secretary—R. B. Glass, Dept. of Transport, Room B 120, Ottawa, Ont.
Board of Managers—A. D. Hazelgrove, W. F. McGarry, G. J. Sanscartier, D. E. Wilson.

PALMETTO SECTION

Chairman—R. E. Faucett, General Electric Co., Hendersonville, N. C.
Vice-Chairman—M. W. Thompson, General Electric Co., Hendersonville, N. C.
Secretary—Joseph Schandler, 47 Merriman Ave., Ashville, N. C.
Board of Managers—P. D. Burrell, R. N. Campbell, J. R. Smyre, E. M. Williams.

PHILADELPHIA SECTION

Chairman—W. G. Speed, Hopkin Brothers, Inc., 120 N. 7th St., Philadelphia, Pa.
Vice-Chairman—R. P. Shelly, Westinghouse Electric Corp., Philadelphia, Pa.
Secretary—S. W. Purdum, Philadelphia Electric Co., 211 S. Broad St., Philadelphia, Pa.
Board of Managers—G. L. Reynolds, P. R. Steele, W. V. Wivel, E. W. Zimmers.

PITTSBURGH SECTION

Chairman—J. B. McNall, West Penn Power Co., Cabin Hill, Greensburg, Pa.
Vice-Chairman—H. J. Mazur, Westinghouse Electric Corp., Pittsburgh, Pa.
Secretary—L. W. Hornfeck, 711 Penn Ave. Bldg., Pittsburgh, Pa.
Board of Managers—J. S. Frizzell, H. S. James, J. V. Pernicano, D. C. Thomas.

PUGET SOUND SECTION

Chairman—G. D. Wirt, Puget Sound Power & Light Co., 286 4th St., Bremerton, Wash.
Vice-Chairman—D. A. Olson, D. A. Olson Co., Seattle, Wash.
Secretary—G. F. Fitzmaurice, Beverly A. Travis & Associates, 1117 2nd Ave. Bldg., Seattle, Wash.
Board of Managers—D. G. Cline, R. L. Dilworth, E. A. Matlock, J. H. Wells.

ROCHESTER SECTION

Chairman—Carl Pollack, 172 Hemingway Drive, Rochester, N. Y.
Secretary—G. R. Butler, Rochester Gas & Electric Co., 89 East Ave., Rochester, N. Y.
Board of Managers—A. G. Elley, H. S. Glick, W. H. Louden, A. R. Principe, R. C. Simmons.

ROCKY MOUNTAIN SECTION

Chairman—J. E. Watson, Fluorescent Maintenance Co., 1427 Elati, Denver, Colo.
Vice-Chairman—F. H. Rosenquist, Public Service Co. of Colorado, Denver, Colo.
Secretary—G. N. Cloos, Gregg N. Cloos Co., 977 Jackson, Denver, Colo.
Board of Managers—H. F. Gypson, E. D. Heintze, G. H. Patterson, R. S. Schrenk.

ST. LOUIS SECTION

Chairman—P. Q. Olschner, Westinghouse Electric Corp., 411 N. 7th St., St. Louis, Mo.
Vice-Chairman—N. L. Krause, Sachs Electric Corp., St. Louis, Mo.
Secretary—H. E. Thias, Union Electric Co., 315 No. 12th St., St. Louis, Mo.
Board of Managers—Brooks Chassaing, W. N. Mangold, E. W. Stohlmann, Jr., L. M. Wallace, Jr.

SAN DIEGO SECTION

Chairman—R. O. Gray, California Electric Works, 424 8th Ave., San Diego, Calif.
Vice-Chairman—A. J. McCutcheon, Jr., San Diego Gas & Electric Co., San Diego, Calif.
Secretary—P. O. Rich, Coast Electric Co., 744 G St., San Diego, Calif.
Board of Managers—W. M. Beery, G. L. Byrum, F. E. Claycomb, E. C. Rice.

SAN JACINTO SECTION

Chairman—D. L. Copeland, Crouse-Hinds Co., 2801 San Jacinto St., Houston, Texas.
Vice-Chairman—Robert Putterman, R. A. Putterman Co., Houston, Texas.
Secretary—H. D. Weisser, Jr., 9214 Rangely Drive, Houston, Texas.
Board of Managers—R. J. Brentzel, Richard Burnett, R. C. Jung, S. L. Powell.

SOUTHEAST FLORIDA SECTION

Chairman—G. H. Gill, Century Lighting, Inc., 1477 N.E. 129th St., N. Miami, Fla.
Vice-Chairman—J. M. Hefley, Rader & Associates, Miami, Fla.
Secretary—Bess Jones, Farry's Wholesale Hardware Co., 7225 N.W. 7th Ave., Miami, Fla.
Board of Managers—H. K. Foster, R. H. Manley, R. L. O'Donovan, F. E. Yanaros.

SOUTHERN CALIFORNIA SECTION

Chairman—Edward Balogh, 3737 Benedict Canyon, Sherman Oaks, Calif.
Vice-Chairman—J. R. Jones, Westinghouse Electric Corp., Vernon, Calif.
Secretary—J. S. Hamel, 234 S. Buena Vista St., Burbank, Calif.
Board of Managers—B. A. Corwin, E. J. Fraser, B. J. Hartmann, J. N. Robertson.

TAR HEEL SECTION

Chairman—E. C. Gatewood, 4400 Callingwood Drive, Charlotte, N. C.
Vice-Chairman—H. J. Chanon, General Electric Co., Charlotte, N. C.
Secretary—D. E. Rouse, Cofer, Rouse & Jeglinski, 1304 E. Wendover Ave., Greensboro, N. C.
Board of Managers—R. C. Browning, J. P. Citron, E. K. Kraybill, J. L. Ponzer.

TENNESSEE VALLEY SECTION

Chairman—D. R. Bills, General Electric Co., 1805 Hays St., Nashville, Tenn.
Vice-Chairman—W. N. Tune, Bond Electric Co., Nashville, Tenn.
Secretary—W. E. Jones, Nashville Electric Service, 1214 Church St., Nashville, Tenn.
Board of Managers—Howard Fisher, J. R. Harrell, Earl Pond, Jr., C. W. Sturdivant.

TORONTO SECTION

Chairman—A. W. Henschel, Shore & Moffat, Architects, 51 Wellington St. W., Toronto, Ont.
Vice-Chairman—A. J. Brown, Mitchell Mfg. Co. Ltd., Toronto, Ont.
Secretary—K. R. Ormrod, Canadian General Electric Co., 830 Lansdowne Ave., Toronto, Ont.
Board of Managers—E. J. Bartley, N. W. Bethune, L. Collins, J. D. Mullock, H. R. Nellis.

TWIN CITY SECTION

Chairman—John Bahnak, 711 W. Lake St., Room 611, Minneapolis, Minn.
Vice-Chairman—C. J. Duepner, B. M. D. & R. Inc., Minneapolis, Minn.

(Continued on page 32A)

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ALL PLASTIC

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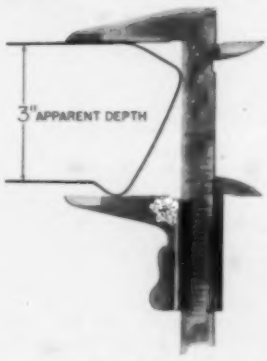
Go modern fast and easy. Specify and install the new wafer-thin, surface-mounted QPCX7400 Sunbeam Visionaires®. A handsome, wrap-around plastic enclosure gives the fixture a semi-recessed look. The diffuser is completely reinforced in metal and may be opened from either side. Exclusive Sunlux® bottom lens panel assures long lasting luminaire efficiency. No "hardware" mars the clean styling.



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(Continued from page 30A)

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Board of Managers—C. W. Frederick, V. W. Furey, D. P. Greene, J. C. Newhouse.

UTAH SECTION

Chairman—W. A. Huckins, Jr., 1320 Laird Ave., Salt Lake City, Utah.
Vice-Chairman—W. C. Brown, Blomquist & Brown, Salt Lake City, Utah.
Secretary—To be appointed.
Board of Managers—Vernon Proctor, H. S. Sherwood.

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Chairman—L. S. Reams, E. I. DuPont de Nemours Inc., Box 1447, Richmond, Va.
Vice-Chairman—R. W. Thomas, Chewning & Welmer, Inc., Richmond, Va.
Secretary—W. M. Amburgey, Jr., Westinghouse Electric Corp., 300 Travelors Bldg., Richmond, Va.
Board of Managers—W. M. Chandler, Jr., W. G. Cornelius, J. S. Ragland, W. A. Sowers.

WESTERN MICHIGAN SECTION

Chairman—S A. Faren, Graybar Electric Co., Inc., 432 Monrow N.W., Grand Rapids, Mich.
Vice-Chairman — J. Q. Miller, Consumers Power Co., Muskegon, Mich.
Secretary—J. W. Gentry, Purchase Electric Supply Co., 700 Ottawa, N.W., Grand Rapids, Mich.
Board of Managers—R. S. Ernsberger, C. F. Kramsvogel, A. B. L. Slenker, W. B. Trimpe.

WESTERN NEW YORK SECTION

Chairman—E. J. Cunningham, Niagara Mohawk Power Corp., 535 Washington St., Buffalo, N. Y.
Secretary—C. S. Long, Jr., Sylvania Electric Products, Inc., 601 Bailey Ave., Buffalo, N. Y.
Board of Managers—T. E. Barhite, Jr., R. R. Herget, J. N. Kellas, W. J. McCarthy, R. J. Walters.

YANKEE SECTION

Chairman — F. P. Hayden, Westinghouse Electric Corp., 119 Ann St., Hartford, Conn.
Vice-Chairman—A. E. Lacas, Western Mass. Electric Co., Pittsfield, Mass.
Secretary—T. K. Haswell, Jr., 141 Birch Grove Drive, Pittsfield, Mass.
Board of Managers—J. E. Cashman, Raymond Coughlin, J. A. Fitzgerald, D. R. Provencher.

NEW MEMBERS

At the meeting of the I.E.S. Council on June 17, 1960, the following were elected to membership. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALAMO SECTION

Associate Members:
Dardar, A. A., Worth Electric Supply Co., San Antonio, Texas.
Hilliard, J. V. Jr., Central Power & Light Co., Uvalde, Texas.

ARIZONA SECTION

Associate Member:
Schreiber, M. B. Jr., Lowry & Sorensen, Phoenix, Ariz.

CAPITAL SECTION

Associate Member:
Merchant, W. S., General Electric Co., Washington, D. C.

CENTRAL ILLINOIS CHAPTER

Associate Member:
Kiefer Electrical Supply Co. Inc., Peoria, Ill.

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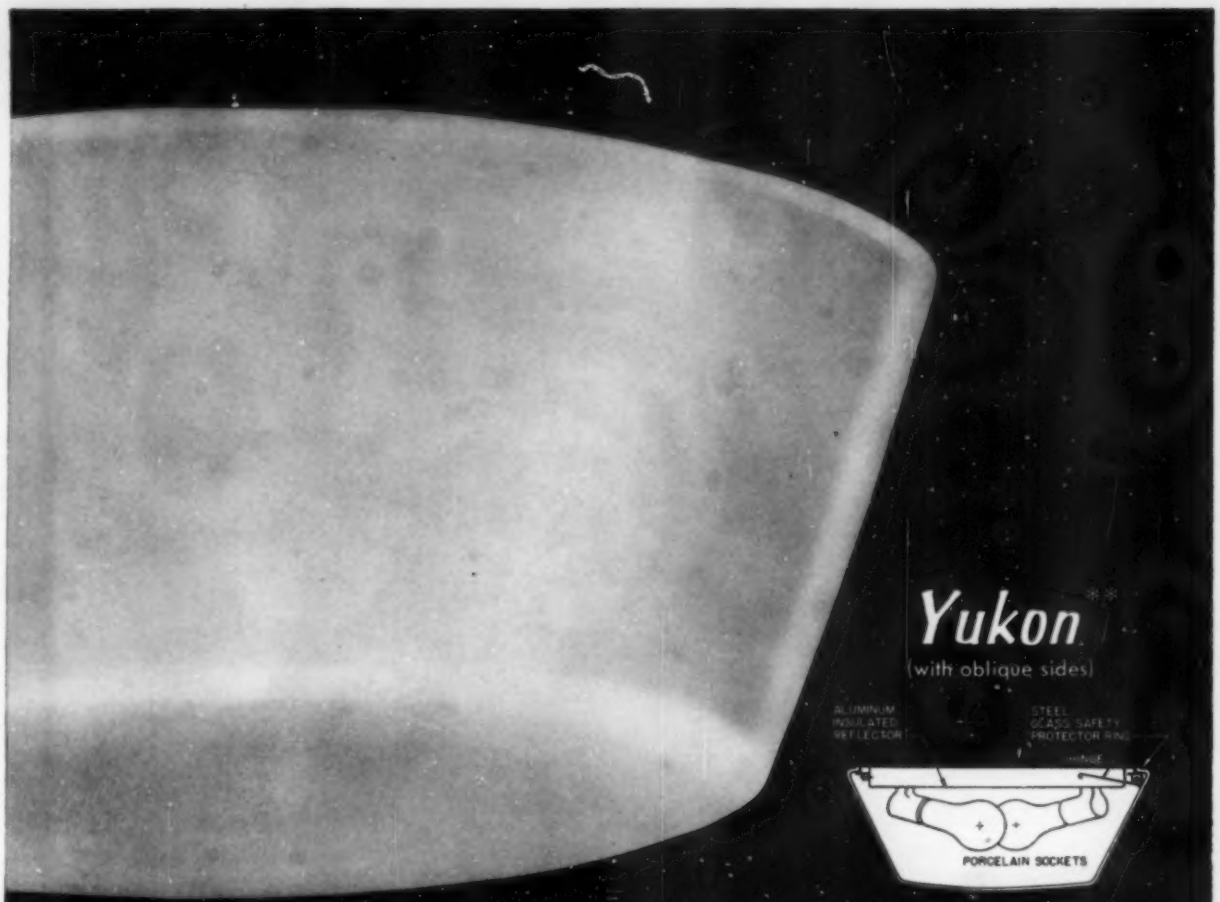

Yukon**

(with oblique sides)

PERFECLITE *Flush-To-Ceiling Fixture Designs*

Klondike*

- **They're Literally All Glass, All Light . . . Have That Built-In Look Without Recessed Construction**
- **Due To A Unique Patented Hanging Device, Nothing Projects — No Metal Shows**
- **Bowls Open On Concealed Disappearing Pivot Hinges . . . Are Secured In Place By A Simple Twist Of The Wrist**

Both the Klondike and Yukon feature interior construction of 20 gauge steel — a baked white enamel steel reflector with heavy aluminum foil reflecting surface and multiple porcelain sockets equipped with #18 AF leads for direct connection to Types R, TW or any 60° C. rated wire.

For further information on either unit, mail the attached coupon today!

*Patented **Patent Applied For
Units are Underwriters' Laboratories, Inc., approved

THE PERFECLITE COMPANY
1457 EAST 40th STREET CLEVELAND 3, OHIO

Please send me the Perfeclite Data Folder 59-C.

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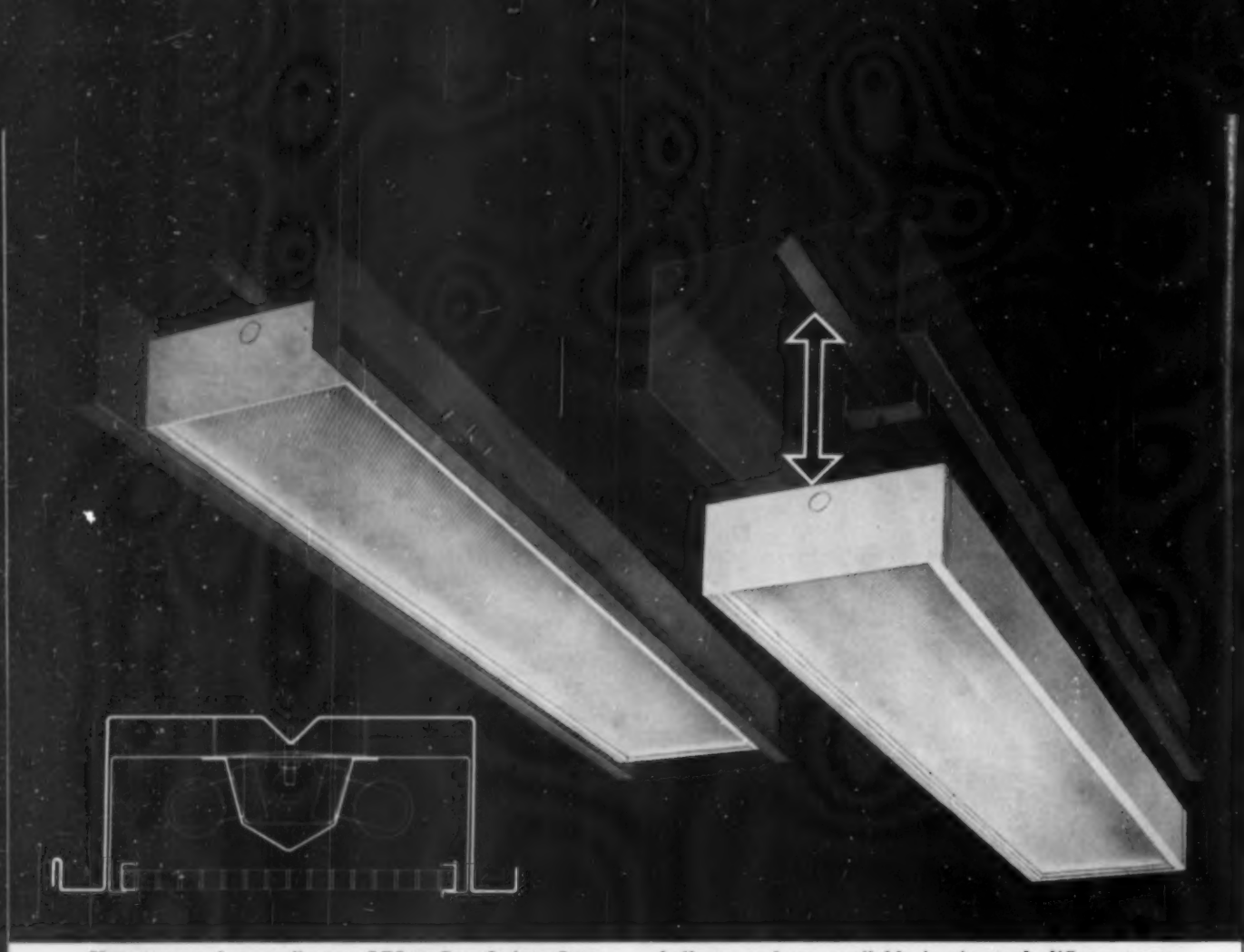
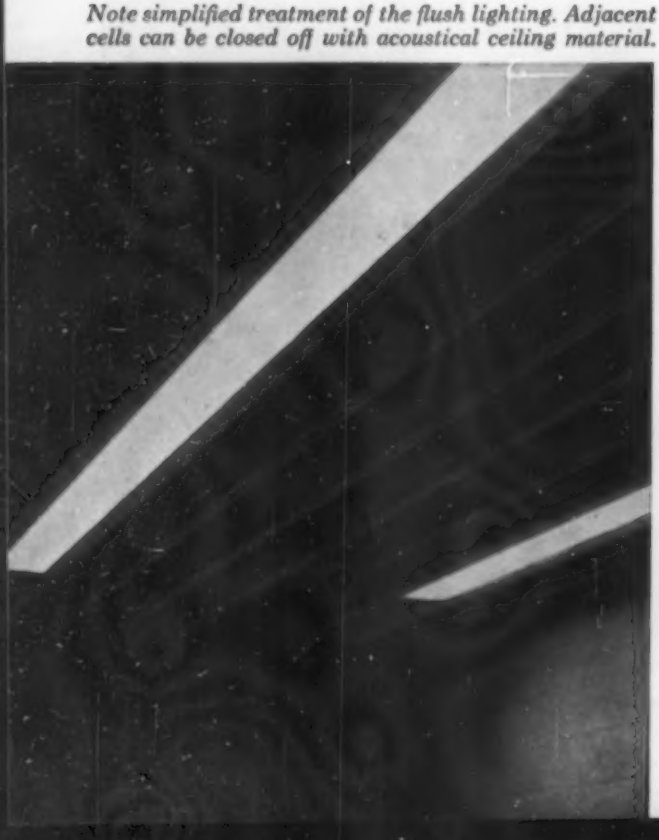


Here you see how easily new LPI troffers fit into flutes of Robertson Q-Deck. These rugged, die-formed steel fixtures are UL-listed with CBM-certified rapid-start ballasts, and are available in six stock diffuser types. Cross section shows simplicity of unit and convenience of installation. Troffers are wired complete, ready to go in.

New LPI troffers for Robertson roof deck

Note simplified treatment of the flush lighting. Adjacent cells can be closed off with acoustical ceiling material.



Versatile Robertson Q-Deck brings all the advantages of quick, clean, dry construction to modern buildings. LPI's new roof deck troffer is specially designed to combine with steel roof deck as a low-cost, functionally handsome ceiling and lighting system.

Architects, engineers, and contractors everywhere are discovering that the happy combination of Q-Deck and LPI troffers installed *within the cells* gives them an attractive low-cost lighting scheme for many new-construction situations.

Self-aligning hangers make for easy installation. Maintenance is simplified by easy-operating framed, hinged diffusers and by ready accessibility of all components. A wide choice of diffusers, including six stock models in formed acrylic, plastic louver, ventrolens, and glass, provides a selection of troffers for all applications.

For more information, write for Roof Deck Troffer Bulletin.

LPI FLUORESCENT LIGHTING

Lighting Products Inc., Highland Park, Illinois

(*Continued from page* 32A)

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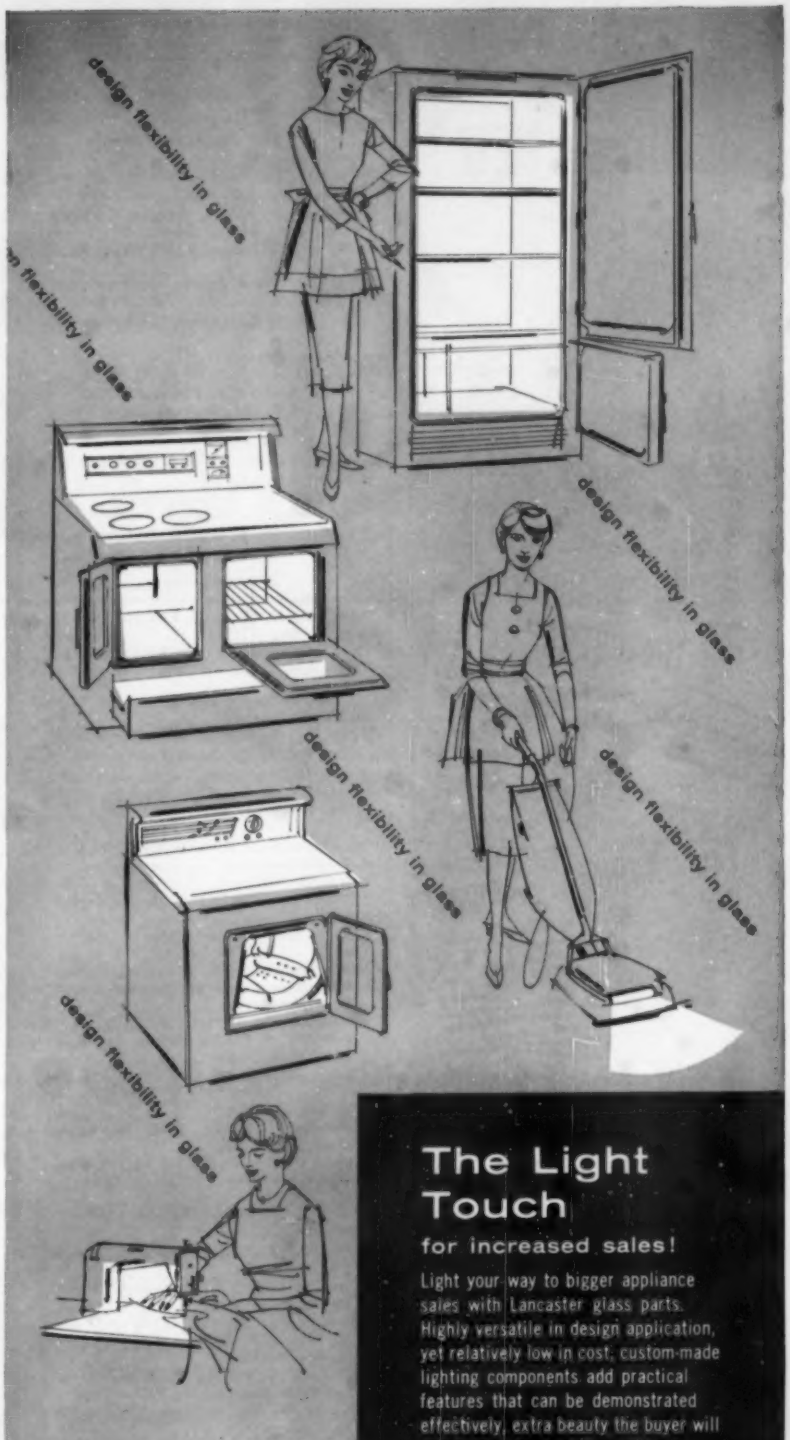
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glass and plastics
to brighten your product's future

Lancaster 5, Ohio

The Light Touch

for increased sales!

Light your way to bigger appliance sales with Lancaster glass parts. Highly versatile in design application, yet relatively low in cost, custom-made lighting components add practical features that can be demonstrated effectively, extra beauty the buyer will appreciate. In short, you will win friends and influence prospects at the vital point-of-sale.

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metco Lighting HAS IT!

The "VEGA"

A new, deluxe quality line of surface-mounted fluorescent fixtures that stresses crisp, slim lines, shallow depth and light-tight framed diffusers.

The "AURORA" Compact

A new economy version of our famous AURORA troffers that offer fine construction and tremendous value. Only 3½" deep! Priced lower than you'd think possible!

The "HI-LO" Wrap-Around

Shallow and modern with a one-piece wrap-around shielding that has a flat, clear prismatic bottom and low brightness sides. Perfect for low-budget installations!

The NEW "ASTRA-LITE"

Best-selling shallow luminaire that features trim, slim design . . . high lighting efficiency . . . and now designed to give even more economy in any application!

WRITE TODAY FOR FULL DETAILS AND CATALOG SHEET

NEMA UL cyo-li

Sold Only Through Qualified Electrical Distributors

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(Continued from page 35A)

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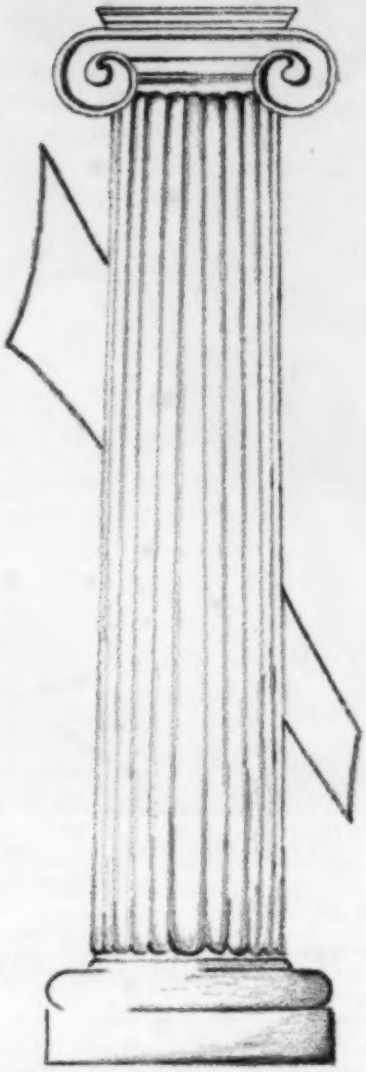


FUNCTION+FORM

Need for structural strength created the column . . . and engineering created its classic form. At SECHRIST good engineering plus modern materials and techniques result in luminaires of optimum photometric performance and natural beauty and grace.

Our STYLE-LINE is a good example . . . see your SECHRIST representative or write us.

SECHRIST MFG. COMPANY
BOX 6775
Denver, Colorado
Leaders in Lighting . . . Since 1888

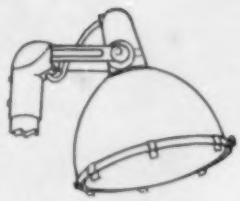
Revere Outdoor Lighting Report

Revere ELECTRIC MFG. CO.

Lighting an automobile sales lot

The Problem: To illuminate a long, deep sales area so that cars, signs, and buildings would attract attention and look more appealing to passers-by.

The Answer: Five poles, each mounting ten Revere No. 7403 *1000-watt* mercury floodlights on a No. 217-ZA bracket, were installed to provide the high level of lighting desired. Ten No. 3510-AL Revere Par Lamps are also mounted on each pole 10 feet above grade to highlight the color and beauty of the cars and create more sales appeal.

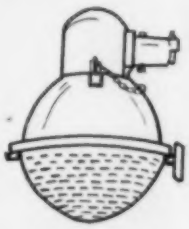


No. 7403 Floodlight

Lighting a city street

The Problem: To provide a lesser traveled secondary street with uniform, moderate-level lighting, in the most efficient, economical way possible.

The Answer: Revere Star-Lux incandescent street lighting luminaires were installed on converted concrete poles to provide efficient lighting at low cost. The Star-Lux uses up to 10,000 lumen incandescent lamps or 250 to 400-watt mercury lamps to provide any of the five standard A.S.A.-I.E.S. distribution patterns.

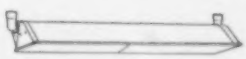


No. 2311-A/2363
Star-Lux Luminaire

Lighting a poster board

The Problem: To assure greater night visibility of an advertiser's poster board sales message by providing higher level, more uniform illumination.

The Answer: Revere Fluoresign outdoor luminaires with very high output fluorescent lamps were installed to give the high level of illumination desired. Reflector and lamp assembly may be positioned at any desired angle for uniform light distribution. Lamps give 10 times the rated life of incandescent types. Fixtures are unobtrusive, too.



Fluoresign Luminaire

Write for Revere's complete catalog of outdoor lighting equipment

Revere ELECTRIC MFG. CO.

OUTDOOR LIGHTING

Revere Electric Mfg. Co. • 7420 Lehigh Avenue • Chicago 31, Illinois

Available in Canada thru Curtis Lighting, Ltd., Leaside, Toronto, Ontario

ABOVE ALL:

Styrene lighting louvers molded of
LUSTREX PERMA TONE

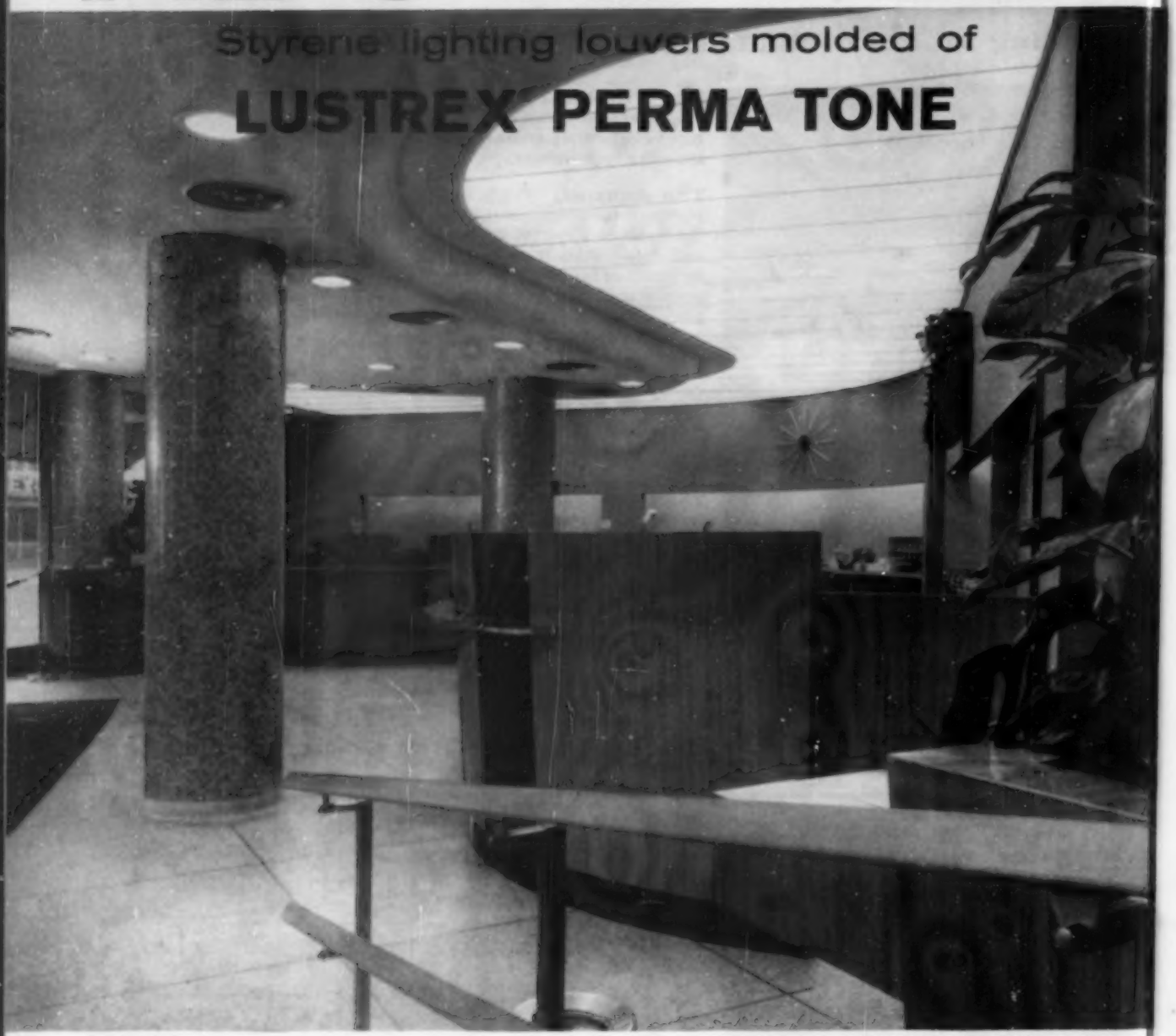


Photo: Courtesy of Electro Lighting Corp., Chicago, Ill.

More Lustrex perma tone is used for lighting fixtures than any other ultraviolet light-stabilized styrene.

In clear white and a complete color range, it exceeds IES-NEMA-SPI joint specifications for ultraviolet light-stabilized styrene. With perma tone you can create low cost large areas of illumination with good diffusion, dimensional stability, and uniform light distribution.

New Impact Lustrex perma tone provides extra toughness and flexibility for snap-fitting to metal parts, high resistance to abnormal abuse, lighter weight through thinner walls. For free technical report on both regular and impact Lustrex perma tone styrene, including accelerated aging test results and other valuable data on styrene in lighting fixtures, write to Monsanto Chemical Company, Plastics Division, Room 782, Springfield 2, Massachusetts.

LUSTREX: Reg. U.S. Pat. Off.

Monsanto

MONSANTO ORIGINATOR IN **PLASTICS**

(Continued from page 36A)

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This unretouched photo shows how we demonstrate the rugged strength of Guth's Tetragonal design, Alzak Aluminum Reflector. Fred Guth (Mr. Chief Tester, himself) stands right on it. We know this rugged Guth reflector will hold at least 300 pounds!
This is typical of the quality and ruggedness you find in Guth Brascolite Incandescents. They're built for rugged duty PLUS optimum and long life lighting performance!
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brascolite
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The Tetragonal Reflector is used in our Square Recessed Brascolites
THE EDWIN F. GUTH COMPANY
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Facts of Light!

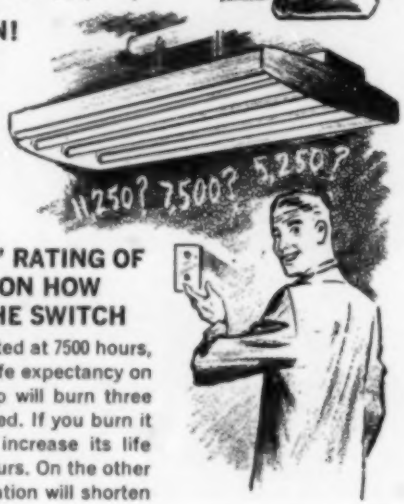
CHAMPION Lamps

TUBES ARE MORE ECONOMICAL THAN BULBS BUT —

For lighting systems in general, incandescent lamps have a relatively low initial cost and a relatively high operating cost. Just the reverse is generally true for fluorescent lamps. In the long run, fluorescent lamps prove the most economical. In the average school building, for instance, fluorescents begin to be more economical in from 3-4 years. However, incandescents would provide the most light for an initial expenditure.

LIGHT BULBS ARE A BARGAIN!

50 years ago a 100 watt bulb cost $1.45. In fact, if 1910 production methods attempted to supply today's demand, a 100 watt bulb would cost about $4.10. Today, you can buy a much better 100 watt bulb for 25 cents list.



THE "7500 HOUR" RATING OF A LAMP DEPENDS ON HOW OFTEN YOU FLICK THE SWITCH

When a fluorescent lamp is rated at 7500 hours, the manufacturer bases this life expectancy on the assumption that the lamp will burn three hours for every time it is started. If you burn it ten hours per start you will increase its life roughly 50% to about 11,250 hours. On the other hand, one-hour per-start operation will shorten its life to about 5,250 hours.

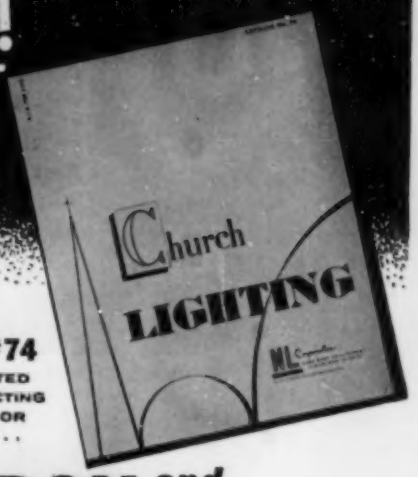
MANY COST-SAVING HINTS IN THE CHAMPION LIGHTING MAINTENANCE MANUAL

This manual explains the principles and advantages of good lighting practice in 48 pages. Included are sections on group replacement of lamps, cleaning programs and a guide to trouble shooting fluorescent installations. This is the latest edition of a guide that has proved to be of great practical value to lighting men everywhere. Write for a free copy.

CHAMPION LAMP WORKS, Lynn, Massachusetts

CHAMPION INCANDESCENT-FLUORESCENT • *YOUR BEST BUY IN LAMPS*

FREE!



NEW CATALOG #74
BASIC ILLUSTRATED GUIDE FOR SELECTING CONTEMPORARY OR TRADITIONAL . . . . .

CHURCH *and institutional* **LIGHTING**

Assistance from field representatives available at no obligation

Write Today!

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Designers and Manufacturers...Since 1905

ATI GIMBALS ARE PROFIT SYMBOLS

ATI quality features assure better acceptance, better profits and repeat sales.

ATI GIMBAL RINGS offer:

1. Trouble-free, long-life construction.
2. Cost saving adaptability and versatility.
3. Attractive cadmium plate, brushed chrome effect, may be used as plated or will oct as excellent paint base.

Write, wire or call for details

GIMBAL RING for PAR 38, 46, 56 and the 64 sideprong lamps.

GIMBAL RING for R30, R40 and PAR 38 screw-base lamps.

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OSborne 5-7200

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Third Edition

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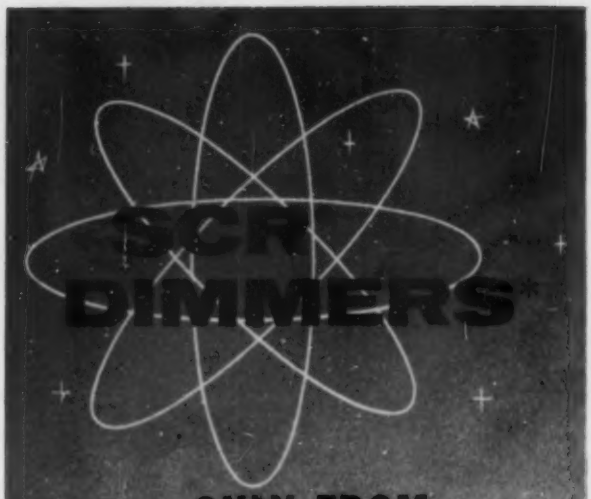

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*REGISTERED TRADE MARK
*PATENTED

From discovery to distribution it's a Kliegl innovation. SCR® Dimmers* are available from only one source . . . Kliegl Bros.

SCR® Dimmer* capacities have recently been expanded to include 3KW, 6KW, 10KW and 12KW units.

The patented back to back circuit, feather weight and job tested reliability found in SCR® Dimmers* are outstanding examples of the imagination, forward thinking and engineering know-how that is found in every Kliegl product . . . products which have made Kliegl "The Great Name In Lighting".

For complete information on SCR® Dimmers, write*

lighting
KLIEGL BROS.
UNIVERSAL ELECTRIC STAGE LIGHTING CO., INC.
321 W. 50th ST., NEW YORK 19, N. Y.
ORIGINATORS AND MANUFACTURERS OF KLIEGLIGHTS

Twenty-four 1000w color-corrected mercury lamps, spaced on 20 x 30 ft. centers, are mounted 50 ft., 6 in. above floor. Maintained illumination is 30 footcandles. Installation — *Metropolitan Edison Co., Reading, Pa., Portland Station.* Electrical Contractor—*H. N. Crowder Co.,* Engineers and Consultants—*Gilbert Associates, Inc.*

Sola transformer No. 77020 maintains rated lumen output of H15 lamp in Holophane fixture within ±1% even if primary voltage should vary over 200 to 260v range.

Newest line of indoor Sola constant-wattage mercury-lamp transformers features light weight, improved case construction; starts mercury lamps down to 20° below zero.

Sola-ballasted mercury lamps specified for new generating station

Here are five performance benefits that make Sola constant-wattage transformers pay off in modern mercury lighting installations: Light output is constant within ±1% with line voltage changes as great at ±13%. Line-current starting surge is limited to normal operating value—eliminates need for heavier wiring, time-delay relays. The constant-wattage circuit limits primary current under abnormal conditions—lamp failure or secondary short circuit will not overheat the transformer. Stable operating conditions insure rated lamp life. Line voltage must dip 30% below nominal before lamps extinguish.

The utility's engineers and consultants recognized these benefits and specified constant-wattage transformers. Consult your Sola lighting representative for further information, or write for Bulletin MV-396.

SOLA

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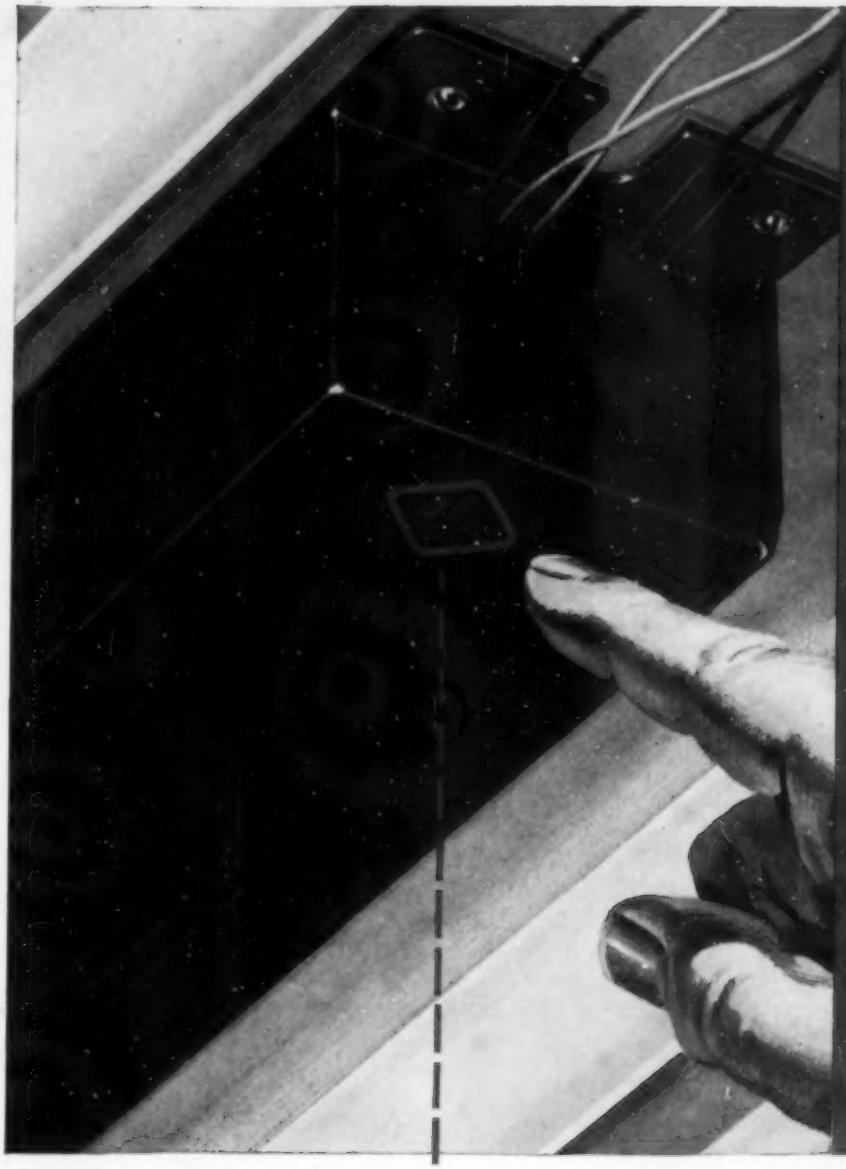

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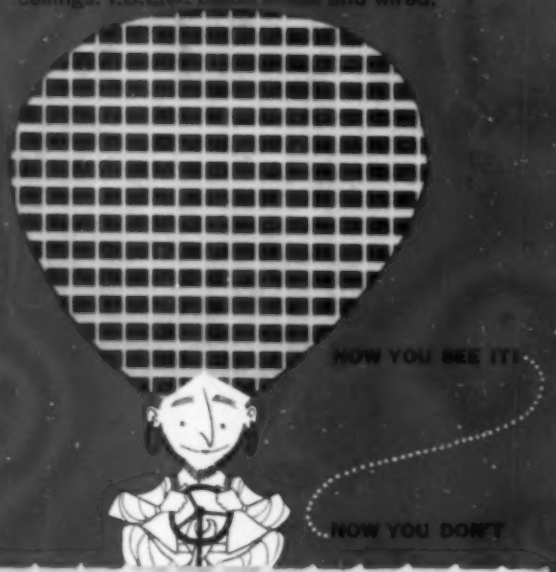

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